

***Preaching to the converted***

JOHN WILLIAM HINCHLEY, that remarkable genius with a burning zeal for creating chemical engineering as a profession distinct from chemistry and mechanical engineering, was not only gifted in the many branches of science and engineering with which he came into contact during his eventful career, but was also steeped in the humanities and deeply concerned with social reform. (In later years he boasted that at the age of 19 he had taken the chair at a Fabian Society meeting addressed by no other than the irrepressible George Bernard Shaw!) It is most fitting, therefore, that the lectures, delivered every few years to the Institution of Chemical Engineers as a memorial to Hinchley, should reflect the broader, more philosophical implications of chemical engineering.

Prof. P. M. S. Blackett, who recently delivered the tenth Hinchley Memorial Lecture, is, like Hinchley, a great man of science and passionately interested in social problems. His lecture, entitled 'Science and Technology and the Developing Countries', dwelt on a subject very near his own heart; he has been expounding on this theme for many years, notably at past meetings of the British Association. Yet did he shed any new light on this enigma?

His introductory analysis of the average world distribution of income was startling: £400 per head in the Western countries and only £40 in the undeveloped countries. He stated that, in order to bring about a rise in individual annual income of 2% with a population rise of 2%, a total rise in wealth of 4% is necessary—to achieve this a rate of national investment of at least 12% is required. Such investment can come from either internal taxation or gifts from abroad. Needless to say, undeveloped countries will require all their investment in the form of gifts, and here a most important point arises. How are these gifts to be invested so that they yield the maximum benefit? This point was illustrated by some calculations made several years ago by the Indian scientist Mahalanobis when estimating how best to satisfy India's requirements for wheat to feed her rapidly increasing population. One way of doing this was by importing 700,000 tons of wheat costing \$400 in foreign exchange; an alternative way would be by importing 300,000 tons of ammonium sulphate to raise crop yields by this amount.

A third way would be to build one fertiliser plant a year costing \$100 million, of which only \$60 million would be in foreign exchange. Proceeding from this argument, it would cost even less in foreign exchange to build a plant to manufacture plant—but the return in extra food would be still longer delayed.

Prof. Blackett then attempted to relate these generalities to possible developments in chemical engineering.

He made the suggestion that, if chemical plant were designed for undeveloped countries, they should take into account the abundance and cheapness of native labour. Taking the typical large plant suitable for a highly industrialised community as a standard, one could envisage three other types of plant. Firstly, an equally large plant designed to reduce capital cost to a minimum, *i.e.* by using more labour; secondly, a smaller type of plant with a high capital cost but suitable for an advanced country; and, thirdly, a small plant with the lowest possible capital cost. Detailed study of such relative projects by chemical engineers would therefore be of utmost benefit to the undeveloped countries.

But surely, as Sir Harold Hartley pointed out after the lecture, chemical plant constructors have constantly advocated such an approach. Chemical engineering has always worked closely with economics and a study of the optimum size of plants has resulted in the 'package plant' so popular in smaller and less industrialised countries. The fault of supplying over-productive and high-capital cost plant to undeveloped countries must rather be attributed to politicians, often motivated by ambitions to outdo their opponents in the cold war.

It is to these politicians that Prof. Blackett's assiduously gathered data should have been addressed—at the Institution of Chemical Engineers he was really only preaching to the converted.

***Safety***

ALTHOUGH we pride ourselves on our good standards of industrial safety, accident figures recently given in Parliament are still alarmingly high. Provisional figures for 1960 show that there were 190,000 accidents reported in all premises covered by the Factory Act, 665 of them fatal. These figures represent a considerable increase over the 1958 and 1959 figures. No breakdown of individual industries is at present available but past analyses have shown that the chemical industry has one of the best safety records.

This is, no doubt, due to the extra precautions which are always taken when handling potentially explosive or inflammable materials. The majority of accidents usually occur under quite different situations: tripping over debris, collapse of stacked shelving, electrocution due to faulty wiring, etc. Such minor mishaps could be prevented in most cases if sufficient foresight and common sense were applied in a works.

Mr. Gardner's article in our special feature on safety classifies such factors, which are intrinsically harmless but do none the less lead to serious accidents. Explosion prevention, on the other hand, has become an exact science during the past 20 years and Dr. J. H. Burgoyne, one of the leading experts in this field,

discusses its principles in another article of this feature. Perhaps only when other branches of accident prevention are studied as fundamentally as explosion prevention will there be a general improvement in our overall standards of industrial safety.

### **Too many codes**

**T**HE recent symposium on 'Pressure Vessel Research Towards Better Design', arranged jointly by the Institution of Mechanical Engineers and the British Welding Research Association, was the first international gathering ever held which was entirely devoted to pressure vessels. Several hundred delegates attended from all over the world and altogether 14 papers were presented. Apart from the mechanical and physical criteria involved in designing pressure vessels it is of great importance to understand the significance of the various laws, regulations and codes which govern the construction of welded boilers and pressure vessels in many countries.

J. F. Lancaster of the Kellogg International Corp. presented a very interesting paper comparing these various codes with respect to their usefulness to the pressure vessel designer. Apparently the degree of actual governmental control over pressure vessel construction varies from country to country; on the one hand there are countries such as Italy and Austria where rules for construction are set out in detail in a ministerial decree whilst in the U.K. the law gives only a minimum of guidance in construction. Despite these variations, general safety standards achieved all over the world are uniformly high—failures of welded pressure vessels are rare and when they do occur are not normally associated with deviations from the normal standard of construction.

The question that may well be asked, therefore, is what essential functions do the boiler and pressure vessel codes serve and to what extent does the existence of such codes achieve a high standard of safety? Lancaster discussed this aspect, citing the example of Belgium and Israel, which have neither codes nor any governmental supervision, yet achieve adequate safety standards. There may, indeed, be a positive disadvantage in detailed and rigid legal codes because of the rapid development of industry using pressure vessels. Any standards must therefore be flexible and capable of amendment; their objective should be to attain conformity to safety standards by collective action rather than by legal compulsion. Another function of a code should be standardisation.

Unfortunately, as far as this country is concerned, a major obstacle to effective standardisation is the existence of three main codes applicable to pressure vessels and boilers. There are the B.S. codes which include B.S. 1113 and 1500, Lloyds rules and the A.O.T.C. rules.

It was felt, therefore, that the establishment of a single boiler and pressure vessel code having a single administrative body would be a most desirable step towards standardisation and economy throughout the world.

### **Nuclear power in the Antarctic**

**A** 1,500-kW nuclear power plant called PM-3A has been commissioned by the U.S. Atomic Energy Commission and will be installed by the end of this year at McMurdo Sound, main base for all American scientific operations in Antarctica. PM-3A has been described by various American sources as the first power reactor that will be making a profit, because government-computed cost curves have indicated that only 4.3 years after its start-up the cumulative construction and operating expenses will be less than those of a comparable diesel plant.

The reactor will be a pressurised water plant using a core of stainless-steel tubular fuel elements. The nuclear fuel consists of a cermet mixture of highly enriched uranium dioxide and stainless steel powder contained in the thin wall of each of the 732 tubular elements. It is sandwiched between an inner and outer cladding of stainless steel so that the water which acts as both moderator and coolant can flow in a single pass around and through each tube.

To increase the life of the reactor core without greatly enlarging its size or creating difficult control problems, 75 'poison' rods of natural boron in a stainless-steel alloy will be interspersed with the fuel rods. Thus at the beginning of its life the boron will absorb neutrons rapidly enough to provide a substantial extra control margin so that the reactor can be shut down even if one of the control rods becomes jammed whilst out of the core. As the nuclear fuel is gradually depleted the poison will burn away to maintain the proper balance of reactivity. The power plant must also withstand uncommonly severe weather conditions—wind loads of up to 100 m.p.h., temperatures ranging down to -60°F. and snow loads of 30 lb./sq.ft. Special precautions will have to be taken in handling fission wastes, which will have to be stored on-site and ultimately shipped back from Antarctica for disposal.

### **Foothold in common market**

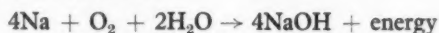
**Y**ET another indication that the trade division of Europe is unnatural was given recently when I.C.I. announced that they would soon begin manufacturing operations on a substantial scale within the European Common Market. The selected location is to be near Rotterdam where the company intends to purchase a site of 300 acres. Construction is expected to commence next year and it is envisaged that up to £100 million will be spent on this project. It may be assumed that the Rotterdam complex will resemble the £120-million Wilton plant (as well as the Severnside complex now under construction) and will produce petro-chemical products like ethylene, propylene, ethylene oxide and ethylene glycol and the appropriate range of plastics and synthetic fibres, polyethylene and polypropylene and *Terylene*. Choice of Rotterdam as location is presumably dictated by its proximity to Europe's largest oil refinery, Pernis, besides being close to the German markets by road, rail or canal.

This new venture should give the government plenty

of food for thought. Protracted negotiations have been going on for the last few months between this country and the Six with a view to arranging a *modus vivendi*. British industrialists apparently do not believe that any mutually acceptable agreements will be arranged and, in order not to lose their European markets, are establishing manufacturing units within the E.E.C. (whose countries, incidentally, quadrupled their petro-chemical production between 1955 and 1959). Such trends cancel out any efforts made by British industry to expand exports. Will the government see this point before it is too late?

### Power from fuel cell

ONE of the first large-scale applications of the fuel cell principle to power requirements was revealed recently when the U.S. Bureau of Ships placed an order with the M. W. Kellogg Co. for the design of a complete power plant as a prototype of a naval power plant. Kellogg's new fuel cell is a continuous-feed primary electric battery in which energy from a chemical reaction is directly converted to electrical energy rather than appearing as heat. In this sodium amalgam cell the basic reaction can be expressed as follows:



This reaction, although it has been known for some time, has been very difficult to harness usefully, due to the great reactivity of sodium—an attempt to use pure sodium would probably lead to an explosive reaction.

The principle of operation of this fuel cell is that a dilute sodium amalgam is supplied to the cell forming a thin flowing film on the surface of a steel plate; this becomes the anode. Oxygen gas is supplied to the hollow cathode—one surface of which is a specially formed porous plate of sintered metal or carbon. An aqueous solution of sodium hydroxide fills the space between the electrodes. Electric power is withdrawn from the cell by external connections to the amalgam anode and the oxygen cathode.

As the process continues, electric energy is steadily generated through the external circuit, sodium and oxygen are consumed and caustic soda is formed in the electrolyte; this becomes increasingly concentrated.

Successful design of a fuel cell is only a small part of the problem of developing a fuel cell power plant. The complete plant will include not only a system of chemical supply but also means of controlling amalgam and electrolyte concentration, as well as sensing, circulation and heat-transfer equipment—to remove the heat generated in the cells. A number of cells will be connected in series in order to produce a satisfactorily high voltage. This is therefore a miniature chemical process plant which will develop about 75 kW. Compared with the hydrogen-oxygen fuel cell (which we discussed recently—CPE, October 1960, p. 434), the sodium amalgam-oxygen fuel cell offers considerable advantages of sharply decreased plant volume and higher efficiency.

### Denmark's nuclear programme

WHY do small countries pursue expensive atomic energy programmes? The answer to this question is not always because of their thirst for basic knowledge. The national status symbol nowadays has become investment in a costly nuclear programme; many nations feel that they have 'arrived' once they can boast of at least a single research reactor. This fashion consciousness, although it has many drawbacks, does none the less contribute to furtherance of knowledge in nuclear science and technology. Denmark, however, although one of Europe's smaller states, has a tradition of nuclear science dating back long before this subject became 'fashionable'—indeed, one of the fathers of nuclear physics, the illustrious Niels Bohr, carried out most of his revolutionary investigations at Copenhagen's Institute for Theoretical Physics and is still today actively associated with the Danish Atomic Energy Commission.

The outlook of the Danish Atomic Energy Commission is, as a result, inclined towards fundamental research. The Commission's research establishment is located at Risø, west of Copenhagen. There are at present three reactors in Risø, DR1, DR2 and DR3. DR1 is a small homogeneous reactor with enriched uranium as uranyl sulphate in light water. It became critical in August 1957 and has been used mainly for training purposes. DR2 is an open-tank-type, light-water reactor with enriched uranium MTR fuel elements. It became critical in December 1958 and is used mainly for neutron beam experiments, isotope production and for irradiation experiments on small samples. DR3 is a heavy-water enriched uranium reactor similar to PLUTO at Harwell. This reactor became critical in January 1960 and is used for materials testing. Besides these reactors there is also a linear accelerator which is used for experiments in connection with food processing.

In devising a research programme for power reactors the Danish Atomic Energy Commission wisely limited itself to those types which are likely to be of importance to Denmark—the gas-cooled, water-moderated and organic-moderated reactors. By participating in joint European projects—the Halden project comprising a water-cooled reactor and the DRAGON project comprising a gas-cooled reactor—wide experience in these systems will be gained by Danish scientists.

Apart from this, exploratory work is at present carried out on the design of a deuterium-moderated organic-cooled power reactor (DOR), which is planned to give a thermal output of 300 MW. The fuel element for this will be based on  $\text{UO}_2$  pellets. Of particular interest are heat-transfer investigations carried out in connection with the organic cooling medium—especially designing an instrument for determining thermal conductivity.

This combination of national and international research will be of utmost benefit to Denmark—it is the only way in which nuclear research can be effectively pursued by small countries wishing to gain the maximum benefit.



## Chemistry and forgery

FEW chemists or chemical engineers would readily believe that a profound understanding of the history of chemistry can be of practical importance in spheres quite divorced from the chemical industry. Yet, only recently such historical knowledge was cited as evidence to prove that certain 'Etruscan' sculptures in the New York Metropolitan Museum were forgeries.

The story goes back to about 40 years ago when the museum purchased three life-size figures presumed to have dated from the 'Etruscan' period in the 5th century B.C. Their historical genuineness had been under considerable doubt for some time, according to the museum director, but only lately analytical tests revealed that one of the constituents in their surface glaze was manganese dioxide, which was unknown until the 19th century. (Q.E.D.)

Manganese dioxide was in fact discovered in the early 19th century; it played a significant role in the development of the Leblanc soda industry. The major inefficiency in the early version of the Leblanc process was due to the wastage of chlorine as hydrochloric acid (obtained in the first stage). One method of regenerating chlorine from hydrochloric acid was by reacting it with manganese dioxide as follows:



Only part of the chlorine was recovered and all the manganese dioxide lost as manganese dichloride. For this reason, such regeneration proved to be too costly a venture. In 1869, after many years of experimentation, a solution to this problem was devised by Walter Weldon (a versatile genius who started his career as a journalist, taught himself chemistry and eventually became a Fellow of the Royal Society). Weldon's process comprised several steps of blowing air through manganese chloride after this had been treated with calcium hydroxide. In this way the manganese chloride was converted to manganese dioxide, which could be used again for oxidising hydrochloric acid. Prospective forgers of ancient art might be well advised to acquaint themselves with a general history of chemistry!

## Changing energy pattern

THERE is little doubt, as we have often pointed out in these columns, that petroleum nowadays is successfully conquering all the world fuel markets and gradually squeezing out coal which, up to about 15 years ago, was the main energy source. Petroleum's conquest of the American fuel economy became significant during the 1920s when the contribution of coal to the American energy pattern dropped significantly from 80 to 67% while that of petroleum rose from 19 to 32%. Similar structural alterations did not occur in Europe until the 1950s when the contribution of solid fuels to the energy pattern dropped from 79 to 63% and that of petroleum rose from 13 to 25%. (It is worth noting that in both cases the change coincided with a high expansion in national income of 3% p.a.)

In the Soviet Union, too, where there are enormous coalfields that have yet to be exploited, the discovery of new oilfields has changed the energy pattern to the detriment of coal. Coal supplies fell from 80% of overall energy supplies in 1950 to 69% in 1959—petroleum supplies rose from 18% in 1950 to 29% in 1959. Estimates based on the present seven-year plan have allowed for an overall consumption of oil and natural gas to reach 47% compared with 51.3% for coal consumption.

In Europe the rate of change-over will depend to a large extent on price trends. According to present estimates for E.E.C. countries, coal consumption by 1965 should be about the same as at present, 270 million tons, whereas consumption of petroleum products should increase from the present level of 115 million tons coal equivalent up to 192 million tons coal equivalent. These figures have been calculated on the assumption that the price ratio between oil and coal will be stabilised at the present level of about 0.90.

Although the usefulness of chemicals derived from petroleum is steadily increasing, by far the greatest amount of petroleum is still burnt as a fuel. Sir Robert Robinson commented succinctly on this peculiar state of affairs by saying that, once we enter the true era of nuclear energy, the chemical industry of carbon compounds will surely leap ahead and provide many of our chief needs—clothing, building materials and even food; in this Utopia the squandering of carbon resources by their use as fuel should be prevented by legislation!

## Whisky or whiskey?

THE author of the famous Anatolian proverb '*in vino veritas*' would doubtless be reluctant to alter it in order to accommodate the drinking habits of the natives of the British Isles. '*In whisky veritas*' or even '*in whiskey veritas*' might, we feel, be more apposite. Such sensible transliteration would instantly be obstructed by the sceptic who would challenge us to prove the difference between whisky and whiskey. 'What's in an e?' he would jibe, misquoting the bard.

Yet the *e* makes the world of difference. We do not subscribe to the school of thought that explains the intrinsic difference between Scotch whisky and Irish whiskey as being due to various distillation techniques. No, the essential difference between these two heavenly brews lies in the manner in which they are consumed. If you endeavour, as we recently did, to obtain whiskey after 11 p.m. in Dublin, you will find it impossible—unless you request a policeman to direct you to the nearest establishment which assuages nocturnal thirsts. To reproduce similar experimental conditions, try to find a whisky establishment in Edinburgh after 11 p.m. Not a hope that your travail will end in success, because the location of such oases is revealed only to the kilted natives of Caledonia!

Therein lies the difference. Surely it is only by a perfect understanding of such subtle nuances that life becomes worth living!



# Principles of Explosion Prevention

By J. H. Burgoyne,\* D.Sc., Ph.D., F.R.I.C.

*Although most people have a general idea of what an 'explosion' is like, it is not easy to give a definition of this term which is at the same time concise and free from ambiguity. The definition must embrace a range of phenomena from the bursting of pressure vessels to the detonation of solid explosives. In the chemical industry, however, explosions most commonly arise from uncontrolled reactions or decomposition in the liquid or solid state, and from rapid combustion or decomposition reactions of gases or aerosols. It is with this latter type of explosion that this article is most directly concerned, and particularly with explosions of gases and vapours in air.*

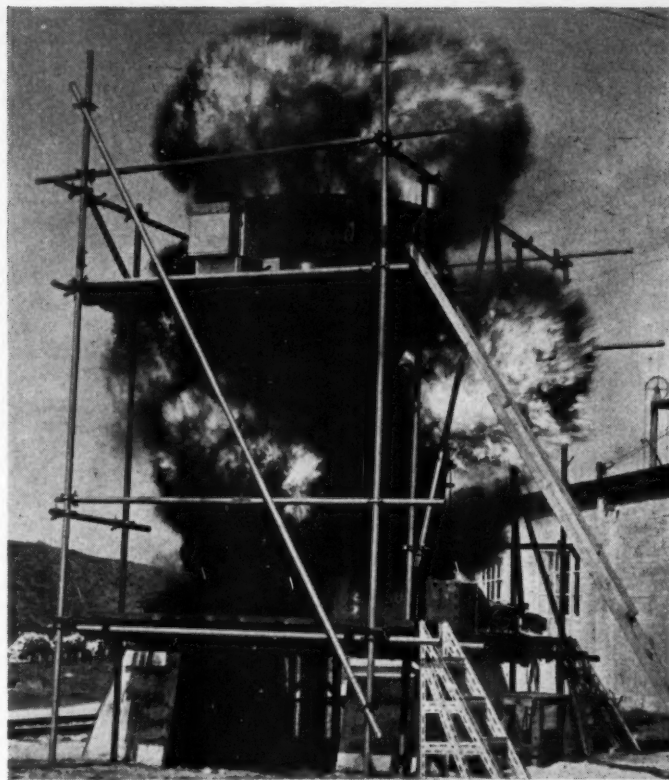


Fig. 1. Experimental coal-dust explosion in pulverised fuel mill. Reproduced from 'Fire Research, 1957', by permission of the Controller of Her Majesty's Stationery Office (S.M.R.E.)

**A**N explosion of the gaseous type is associated with the passage through the explosive gas or mixture of a zone of rapid reaction, i.e. a flame. Flame has to be initiated at some point by a discharge of energy into the gas, and its subsequent passage occurs at a relatively rapid though finite rate. In consequence, chiefly of the heat progressively released during this process, the pressure of the gas is raised quickly if the gas is confined in any way. If the confining vessel or chamber fails under the resultant load, the effects commonly associated with 'explosion' occur, including the projection of fragments and the emission of pressure and sound waves.

Bearing this description in mind, there appear to be three general principles upon which explosion prevention or mitigation can be founded:

- (1) Avoidance of an explosive medium, i.e. a medium capable of transmitting the explosion flame.
- (2) Avoidance of a source of ignition capable of initiating the explosion flame.
- (3) Limitation of the spread and effects of the explosion flame.

It should be noted that the application of these principles is not, in fact, confined to explosions of the gaseous type, but can be extended to 'chemical' explosion hazards generally and also to fire hazards.

## Explosive medium

An inflammable gas will form explosive mixtures with air only if its concentration lies between certain limits, known as the lower and upper limits of explosibility. A distinction is sometimes made between limits of explosibility measured in closed vessels and limits of inflammability measured in vessels open to the atmosphere, but as a rule the differences of value are not large. Limits are usually expressed as percentage by volume and some values for common gases and vapours are shown in the accompanying table (column 1) in these terms. U.S. Bureau of Mines Bulletin 503 (1952) constitutes a comprehensive source of data.<sup>1</sup>

In practice, a common aim is to keep or handle inflammable gases and vapours in air at concentrations below the lower limit. Expressed in volumetric terms, lower limits of various

materials appear to cover a wide range of values. If, however, the proportion of fuel at the lower limit is expressed gravimetrically, a more rational pattern emerges. This is illustrated in Table 1 (column II), in which some lower limits are given as weight of fuel per unit volume of air. The metric unit, g./l., fortunately differs from the English unit, oz./cu.ft., by an amount which is less than the error to which limit values are liable. The units are therefore interchangeable for practical purposes. The following is a summary of lower limit values in these terms:

- (a) For hydrocarbons, whether saturated or unsaturated, aliphatic, alicyclic or aromatic, lower limits are about 0.050 oz./cu.ft., excepting a few materials of low molecular weight which show somewhat lower values.
- (b) The value is greater for materials containing oxygen in the molecule, to an extent depending upon the proportion of oxygen.
- (c) Hydrogen has an exceptionally low value.

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Table 1. Some explosion characteristics of inflammable gases and vapours mixed with air

	Range inflammability in air (vol.%)	Lower limit in air (oz./cu.ft.)	Oxygen limits (vol.%)		Spontaneous ignition temperature (°C.)	Minimum ignition energy (millijoule)	Flame- proof group (B.S. 229)	Maximum burning velocity (cm./sec.)
			With N <sub>2</sub>	With CO <sub>2</sub>				
	I	II	III		IV	V	VI	VII
Methane .. ..	5.3 to 13.9	0.044	12.1	14.6	537	0.29	I	33.8
Ethane .. ..	3.0 to 12.5	0.042	11.0	13.4	472	0.24	—	40.1
Propane .. ..	2.2 to 9.5	0.043	11.4	14.3	466	0.25	II	39.0
n-Butane .. ..	1.85 to 8.5	0.049	12.1	14.5	405	0.25	II	37.9
n-Pentane .. ..	1.5 to 7.8	0.049	12.1	14.4	258	—	II	38.5
n-Hexane .. ..	1.2 to 7.5	0.047	11.9	14.5	240	0.25	II	38.5
n-Heptane .. ..	1.2 to 6.7	0.050	—	—	223	0.25	II	38.6
n-Octane .. ..	1.0 — ?	0.051	—	—	220	—	—	—
Cyclohexane ..	1.3 to 8	0.049	—	—	259	0.24	II	38.7
Benzene .. ..	1.4 to 7.1	0.049	11.2	13.9	580	0.22	II	40.7
Ethyl alcohol ..	4.25 to 19	0.092	—	—	423	—	II	—
Acetaldehyde ..	4.1 to 55	0.085	—	—	185	—	—	—
Acetone .. ..	3.0 to 11	0.080	13.5	15.6	440	—	II	—
Carbon monoxide	12.5 to 74	0.178	5.6	5.9	609	—	II	—
Ammonia .. ..	15.0 to 28	0.137	—	—	651	—	I*	—
Diethyl ether ..	1.9 to 48	0.065	—	—	186	0.19	III	—
Ethylene oxide ..	3.0 to 100	0.054	—	—	429	—	III	—
Ethylene .. ..	2.95 to 28.5	0.038	10.0	11.7	450	0.12	III	68.3
Acetylene .. ..	2.54 to 75.3	0.030	5.7	8.5	335	0.02	IV	170
Carbon disulphide	1.25 to 44	0.044	—	—	120	—	IV	—
Hydrogen .. ..	4.0 to 75	0.004	5.0	5.9	520	0.019	IV	315

\*Ammonia is technically Group I, but is placed in Group II for practical convenience, since Group I is reserved for mining equipment.

### Closed flash-point

In principle, the closed flash-point of an inflammable liquid is the temperature at which its saturated vapour pressure is just sufficient to form a lower limit mixture with air. It follows, therefore, that a liquid below its closed flash-point cannot give rise to an explosive vapour-air mixture in any tank or other closed unit. It must be remembered, however, that where the liquid is dispersed in the free space as a mist (through sudden chilling), as a fine spray (through mechanical disturbance) or as a froth, the dispersed matter takes the place of vapour to a greater or lesser extent, and an explosive mixture can then exist, even though the liquid is at a temperature below its flash-point.

Finely divided mists formed by condensation from the vapours of involatile liquids have lower limit values such as would be expected for the vapour itself, could it exist under the same conditions. For coarse sprays the value is somewhat higher, depending upon drop size.<sup>2</sup>

The upper limits of organic vapours may be extended, under suitable conditions, by a range of mixtures through which cool flames can propagate on ignition.<sup>3</sup> It is believed that the first members of most homologous series, for example methane, ethylene, benzene, methyl alcohol and formaldehyde, have not this characteristic. Neither have certain other molecularly-simple gases such as hydrogen and carbon monoxide. For other members of organic series, however,

the cool flame extension to the upper limit is likely to appear above certain pressures and temperatures, which tend to fall with increasing molecular weight. Diethyl ether and other ethers show this behaviour at and below atmosphere pressure, as does acetaldehyde. With propane and butane, however, elevated temperatures and pressures appear to be necessary.<sup>3</sup>

Cool flames imply an intermediate though specific stage in the completion of combustion, and their explosive effect is mild. At high pressures, however, in the cool-flame range of inflammability, a secondary and more normal flame propagation, representing the completion of combustion, becomes possible following the cool flame.<sup>3</sup> The explosive effect associated with this is at least normally violent. Ignition in the cool-flame range of mixtures is not usually possible with short-lived sources such as sparks, but only with long-lived sources such as hot surfaces or other flames.

### Dilution limits

Ranges of inflammability are narrowed to the point of extinction in the presence of increasing proportions of diluents such as water vapour, nitrogen and carbon dioxide.<sup>4</sup> Some extinguishing materials, such as the halogenated hydrocarbons, appear to have a specific inhibitory effect upon combustion reactions, but otherwise the effect of a diluent is chiefly related to its ability to lower the flame tem-

perature, which in turn is a question of its thermal capacity. For this reason carbon dioxide is more effective than nitrogen. This is illustrated in Table 1 (column III), which shows the point to which the oxygen content of mixtures of various gases and vapours with air must be lowered, by the addition of nitrogen and carbon dioxide respectively, to avoid the possibility of explosible mixtures.<sup>1</sup>

Lower limits are not usually changed very much by the addition of quantities of diluent significantly less than that required for complete extinction of the inflammable range. For this reason lower limits in oxygen are usually similar to those in air and in mixtures of air and oxygen.

### Quenching distances

Ranges of inflammability are narrowed in narrow spaces and are ultimately extinguished at a width known as the minimum quenching diameter or distance for the gas or vapour involved. The shape of the space concerned has some influence on this critical dimension, but for many saturated hydrocarbons and organic vapours in air at atmospheric pressure and temperature, the quenching distance between parallel walls is about 2 mm., whilst for hydrogen it is about 0.6 mm. It seems that quenching distances vary inversely as the pressure of the gas mixture and decrease somewhat with increasing temperature.<sup>5</sup>

It must be emphasised that the quenching distances here described

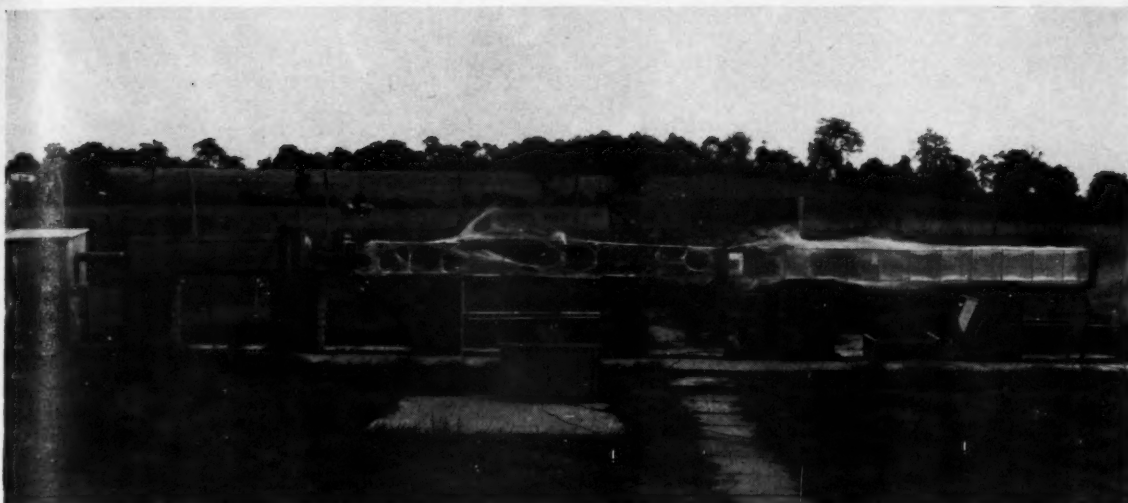


Fig. 2. Gas explosion in polyethylene duct. Reproduced from 'Fire Research, 1957', by permission of the Controller of Her Majesty's Stationery Office

are those which prevent the process of flame propagation by destroying the flame front. This effect is quickly exerted and the length of the channel has little influence on the quenching distance. Thus the quenching diameter is about the same for a round hole in a thin plate as for a length of tube. If, however, the rate of approach of the flame to the quenching gap is considerable, the quenching of the flame in the gap will not prevent re-ignition on the far side due to the streaming of hot product gases.

Flame quenching may therefore not be finally effective in these circumstances even though the gap is below the quenching distance for the mixture concerned. This is the situation that arises in flame arrestors and further reference will be made to it in that connection.

#### Thermal ignition

If an explosive gas mixture is introduced at a sufficient pressure into a vessel at a sufficient temperature, it will ignite spontaneously (*i.e.* flame will appear throughout the mixture) after a certain lapse of time, known as the 'ignition lag'. This lag generally diminishes both with increasing temperature and increasing pressure, but, by reducing either temperature or pressure, a limit for the ignition of a particular mixture can be found and this corresponds with the longest ignition lag available at that temperature or pressure. For a particular fuel in air, the spontaneous ignition temperature at a certain pressure (say atmospheric) passes through a minimum with varying fuel/air ratio and therefore a lowest figure is available

below which this fuel will not ignite spontaneously in air at atmospheric pressure. Some such values are given in the table (column IV).<sup>6</sup>

It will be seen that the figures for the paraffin hydrocarbons fall with increasing molecular weight but that there is a sudden drop between butane and pentane so that, in fact, all the figures are either above 400°C. or below 300°C. Ignitions in the low-temperature range are initiated through the medium of a cool flame, the tendency to which increases with increasing molecular weight and also with increasing ambient pressure.

Thus, while progressive increases in ambient pressure would lower all the figures given in Table 1, butane, propane and ethane would be particularly affected by a transfer of their minimum ignition temperatures in turn into the low-temperature range. So far as is known, however, methane would never take part in low-temperature ignitions. In other homologous series of organic compounds, similar trends are observed, though where reactivity to oxygen is particularly high, especially low ignition temperatures may arise. Thus some ethers and aldehydes have ignition temperatures of less than 200°C. in air at atmospheric pressure.

The lowest temperatures of truly spontaneous ignition are found in closed vessels. Where heating is derived from a surface that is less embracing than a complete vessel, there is some flow of gas mixture relative to the hot surface. For this reason a temperature difference exists between the hot surface and the gas mixture and, therefore, to ignite the

gas mixture, the temperature of the surface must be somewhat above the spontaneous ignition temperature of the mixture. The necessary difference depends upon the size of the surface and the extent to which it embraces the mixture.<sup>7</sup>

Similarly, where the mixture is flowing through a heated tube or vessel, an equipment temperature somewhat above the ignition temperature of the mixture will be required (depending on the flow rate) to effect ignition of the flowing stream.

Much could be written of the details of these situations, but from the viewpoint of safety this seems unnecessary. If the surface or equipment temperature is above the ignition temperature for the mixture with which it is, or may be, in contact, the prevention of ignition depends entirely upon maintaining the flow of the mixture relative to the source of heat. Such flow can fail due to a local pocket or other obstruction on the surface of the source or due to failure of the motive power in a tube or vessel. The mixture will then ignite under static conditions. It is, therefore, necessary to regard the minimum spontaneous ignition temperature as the safe limit of surface temperature even where natural or forced flow of the gas mixture is expected to be the normal condition.

In some cases spontaneous ignition may appear to occur in a vessel where the prevailing temperature is below the minimum spontaneous ignition value. This is probably due to the presence of catalytic particles (*e.g.* metal oxides) which promote the heterogeneous reaction of the gas



mixture. As a result of this the particles will self-heat intensely and can become a local source of ignition of the gas mixture as a whole. The ignition is therefore not truly spontaneous, although it appears to be so.

### Electrical ignition

Generally speaking, the spark derived from the discharge of a condenser in a non-inductive circuit is the most efficient form of local ignition source, in that the discharge of energy necessary to ignite a particular gas mixture by this method is less than for any other method. The amount of energy required varies for any fuel vapour with the fuel/air ratio, and a minimum value, corresponding to the most ignitable mixture, can be located. Minimum ignition energies for various gases with air at atmospheric pressure are shown in Table 1 (column V).<sup>5</sup> The condenser type of discharge arises in practice from accumulations of static electricity, and the ignition energies shown are relevant to the calculation of this hazard.<sup>8</sup> Since energy available from a condenser is given by  $\frac{1}{2} \times \text{capacity} \times (\text{voltage})^2$ , a calculation can be made of the highest safe voltage for a system of known capacity in relation to a gas of specified minimum ignition energy.

Most practical electric circuits are at least partially inductive and in such cases the potential source of ignition is the spark formed on breaking the circuit (*e.g.* at a switch or relay), the energy of which is derived partly at least from that in the electric fields of the inductances. Part of this energy can be diverted from the point of break by applying various types of shunts (*e.g.* rectifiers, short-circuited secondary windings, etc.) to the inductive elements (solenoids, electromagnets, etc.). This is the method upon which 'intrinsic safety' depends.<sup>9</sup> It is more suited to low-voltage circuits than to high, since at high voltages the break spark contains a considerable arcing element upon which the safety shunt has no influence. In practice, intrinsic safety is mostly (though not exclusively) applied with circuit voltages up to 24 or 30.

For high-voltage equipment, protection with respect to explosive mixtures is more usually attained through 'flameproof enclosure'.<sup>10</sup> For this purpose the sparking or potentially-sparking equipment (*e.g.* motor, switch-gear, etc.) is enclosed in a specially constructed metal case. No attempt is made (except as will appear later) to exclude the inflammable gas from this case. The possibility of an explosion

therein is therefore admitted. However, the case is sufficiently strong to contain such explosion without damage and any necessary channels from inside to outside of the case (*e.g.* alongside shafts and spindles) are of such narrow dimensions that any issuing flame is quenched and a surrounding inflammable atmosphere is not ignited.

For certain gases having very small quenching distances, such as hydrogen, acetylene and carbon disulphide, no standard flameproof equipment is available in the United Kingdom. The method of protection of electrical equipment in these cases is either through its complete isolation from the hazard, or through its pressurisation with air or inert gas, whereby the entry of inflammable gas into the case of the equipment is prevented.

For purposes of classification gases have been allocated to four groups numbered I to IV, in order of increasing hazard, Group IV comprising the 'excluded gases' referred to above. This grouping serves the additional purpose of indicating the comparative hazard of initiation (other than thermally) and spread of explosions of the gases concerned, in air. Thus methane (Group I) is comparatively difficult to initiate and easy to suppress, whilst of hydrogen (Group IV) the reverse is true. Flameproof groupings are indicated, where available, in Table 1 (column VI).

### Limitation of spread and effects

In general, the rate of progress of an explosion flame increases as it spreads through the explosive medium, whether this be in a compact vessel or room, or in a long pipeline or corridor. Since the transient pressure effects associated with the explosion flame are related to its speed, the ability to do damage tends to increase as the flame spreads. It may be added that the difficulty of arresting the flame also increases with its speed. There are, therefore, good reasons, apart from the most obvious one, for using every endeavour, first to prevent the explosion flame from ever starting on its course or, failing this, to arrest it at the earliest possible stage by limiting the extent of the explosive medium, or by other means.

When an explosion flame is initiated in and spreads through the explosive contents of a reasonably compact vessel, the pressure rises at an increasing rate until the combustion of the contents is almost complete. The ultimate pressure rise under adiabatic conditions is calculable from the

stoichiometry and thermochemistry of the exploding mixture. It depends upon the fuel/air ratio, but with the most favourable ratio it does not normally amount to more than an eight- to ten-fold increase of the initial pressure. The calculated figure may be approached in practice in a compact vessel free from internal structures. If, however, the vessel is full of internal equipment or packing, heat loss will be considerable, even in the short period of the explosion, and the final explosion pressure will fall short of the adiabatic value. The packing of vessels and spaces with, for example, rods, balls, beads or rings, depending on size and shape, should be noted as a method of reducing the effect of a possible explosion. The thermal properties of the packing are much less important in this connection than the surface area that it presents to the explosive medium.

The rate of rise of pressure in a vessel explosion is at first relatively slow and it is quite practicable to detect this first slow rise automatically and to utilise the signal to disperse suppressant fluid into the vessel in time to quench the main development of the explosion.<sup>11</sup> The application of this method in vessels operating at atmospheric pressure and at temperatures not too far above ambient is reasonably straightforward, but for higher pressures and temperatures certain problems arise.

The rise of pressure due to explosion in a vessel can also be limited by the employment of explosion relief. There is rather little generalised information on the design of explosion reliefs, but the following relation has been developed<sup>12</sup> for explosions in near-cubical chambers in which the relief area is in the top of the chamber and is of such large area that the pressure does not rise above about 3 p.s.i.g.:

$$pV^{\frac{1}{3}} = S_u \left( 0.30 \frac{A_1}{A} W + 0.40 \right)$$

where  $p$  = maximum pressure (p.s.i.g.),  $V$  = volume of chamber (cu. ft.),  $A_1$  = plan area of chamber (sq. ft.),  $A$  = area of relief opening (sq. ft.),  $W$  = weight of relief closure (lb.) and  $S_u$  = burning velocity of explosive medium (ft./sec.).

In this expression the rate of explosion is incorporated as  $S_u$ , the linear rate of progression of the flame front through the explosive medium relative to the unburnt medium. This quantity, the burning velocity, is dependent upon fuel/air ratio, but some maximum values are given in Table 1 (column VII).

For relief at higher pressures, relations become complex and it is necessary to refer to empirical investigations.<sup>13, 14</sup> Relief closures can, if desired, be opened automatically by a signal from the early stage of the explosion pressure rise, as in the application of suppressant fluids.

When an explosion flame traverses an explosive medium in a long pipe it accelerates, either from the point of ignition if the pipe is closed at that point, or after travelling a certain distance if the pipe is open there. The final outcome of this acceleration is that the flame travels as a detonation wave if the mixture is of sufficient potential energy content and the distance of travel great enough. Flame velocities are then in the sonic range and the ability to do damage is correspondingly magnified. From a safety point of view this stage is certainly to be avoided, by keeping out of the detonable range of mixtures (which is well within the ordinary inflammable range) and by avoiding long, uninterrupted runs of explosive medium. Few detonable ranges in air have been established, but the following are given<sup>5</sup> (vol.%): hydrogen 18.3 to 59; acetylene 4.2 to 50; diethyl ether 2.8 to 4.5.

The travel of flame in a pipe may be halted by the intervention of a flame arrestor. This is a device which subdivides the cross-section of the pipe into numerous channels, all of which have diameters less than the quenching diameter for the explosive medium. They also have sufficient depth to cool hot products.

To arrest the flame, the apertures must, of course, be below the quenching diameter for the explosive medium, but how much below depends on their length (*i.e.* the depth of the arrestor) and the velocity of approach of the explosion flame.<sup>15</sup> As velocities of approach cannot be accurately predicted in practice, this conclusion is not particularly helpful. Undoubtedly the difficulty of arresting the explosion of a particular gas in air is indicated by its flameproof grouping<sup>10</sup> (see Table 1, column VI), a low group indicating comparative ease of suppression. It follows from the relation between flame velocity and ease of arrest that a flame arrestor should always be placed as near as possible to the potential source of ignition, if this is identifiable, *e.g.* the burner port in the case of a flash-back arrestor. Otherwise, a flame arrestor placed in a length of pipeline should be closely associated with an explosion relief which will vent the flame pro-

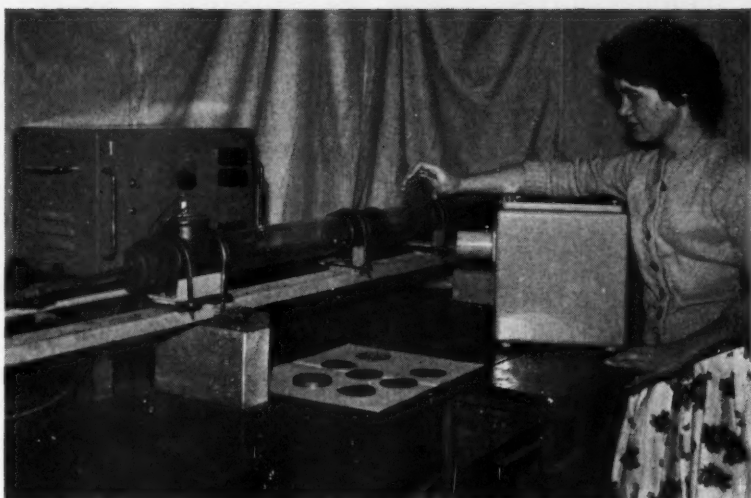


Fig. 3. Insertion of flame arrestor in explosion tube. Reproduced from 'Fire Research, 1959', by permission of the Controller of Her Majesty's Stationery Office

ducts and so reduce its velocity of impact on the arrestor.<sup>16, 17</sup>

It has been shown that gaseous detonations can be arrested by arrestors of the crimped ribbon type, particularly when these are placed in an enlargement in the pipeline.<sup>18</sup> This arrangement is, in any case, commonly adopted for the purpose of reducing the pressure drop associated with normal flow of gases through the arrestor. Explosion reliefs cannot be used to retard detonations, however, unless automatically actuated well in advance of the detonation wave.

### Conclusions

The most satisfactory principle in explosion prevention is the effective elimination of the explosive medium by adequate dilution with air or inert gas, by the elimination of free spaces beyond the quenching dimension, or by other means.

The elimination of effective sources of ignition is not a reliable general principle in prevention since possible ignition sources cannot be listed comprehensively. The minimum amount of energy required to initiate explosion is exceedingly small and any useful form of activity can discharge far larger amounts which, if suitably directed, are amply adequate to effect ignitions. Thus, while every endeavour should be made to eliminate evident potential ignition sources, this course can seldom be safely regarded as the principal line of defence, unless the hazard is very closely defined.

Measures calculated to moderate or suppress the explosive effects also do not constitute a first line of defence

although they have an important secondary function. The behaviour of an explosion flame, once initiated, is not absolutely predictable in practice and measures which depend upon assumptions as to its behaviour cannot therefore be entirely reliable. Once more it is a case of prevention being better than cure.

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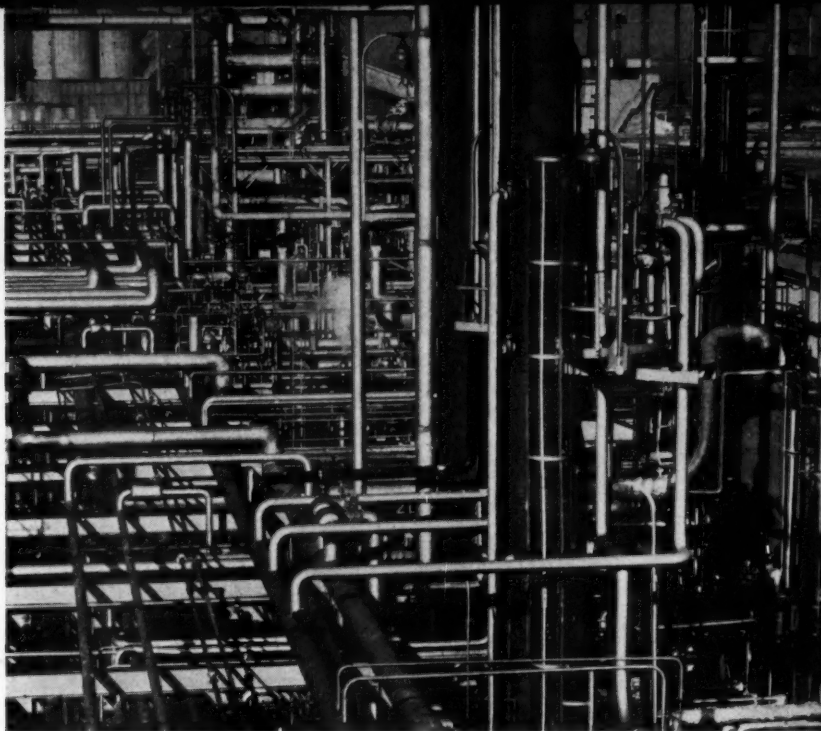
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# Safety in Chemical Plant

By John Gardner\*



The complex nature of a modern chemical plant is illustrated in this photograph. Men must be able to move about and work on the plant safely and the importance of considering such points at the design stage is obvious

*'Comparisons are odious' runs the old saying. And so they are when one tries to compare accident figures in industry. Conditions vary so vastly and the basis on which figures are arrived at is often different. Nevertheless, figures quoted in this article show that the chemical industry has quite a good record with regard to safety. Much, of course, still remains to be done to improve it, since there is no room for complacency.*

THE statistics given at the end of this article indicate that accidents due to falls, handling, etc., in the chemical industry, as in other industries, are responsible for a high proportion of all accidents. In spite of the handling, manufacture and transport of a tremendous variety of hazardous chemicals, accidents from purely chemical causes are relatively few. There are still too many, and further reductions must be made. Sir Thomas Legge, who was appointed the first Medical Inspector of Factories in 1898, put forward four maxims whose application has had an important bearing on reducing chemical accidents.

(1) Unless and until the employer has done everything—and everything means a good deal—the workman can do next to nothing to protect himself, although he is naturally willing enough to do his share.

(2) If you can bring an influence to bear external to the workman (that is, one over which he can exercise no control), you will be successful.

(3) Practically all industrial lead poisoning is due to the inhalation of dust and fume; and if you stop this inhalation you will stop lead poisoning. (While lead poisoning is specifically mentioned, this axiom is clearly meant to have a wider application.)

(4) All workmen should be told something of the danger of the material with which they come into contact and not be left to find it out for themselves—sometimes at the cost of their lives.

Management in any industry would be wise to follow the first two axioms and, as chemicals are now widely used

in many industries, they might with advantage note the other two.

## Chemical hazards

As far as chemical hazards are concerned the first three axioms are concerned with isolating the material from the workmen and avoiding the risk from fire and explosion, toxic or corrosive effect. Except for explosives, whether a fire or explosion occurs depends on prevailing conditions, and the same prevention measures apply to both.

With few exceptions chemicals become dangerous only in well-defined conditions, and fire and explosion risks will be almost entirely eliminated if correct handling procedures are used. There are, therefore, stringent regulations controlling the transport,

\*Corporate Member, Institution of Industrial Safety Officers.

storage and use of some chemicals.

For potentially hazardous materials to cause direct harm to a person they must make contact with him and this is most likely to happen when they are released as a gas, vapour or dust. If, however, these are contained and not released to the atmosphere, he will be protected. Thus, by designing and operating a plant to reduce the escape of potentially hazardous materials, the danger from fire and explosion, toxicity and corrosion is minimised.

However, it is not always practicable to use an entirely enclosed manufacturing process and, even where it is, the plant must be opened from time to time for maintenance. Contact between the workmen and product may also be established in processes such as packaging. Hazardous materials can, of course, enter the body by ingestion, inhalation and through the skin—the latter two are the most likely routes in industry. To guard against the inhalation of gases and vapours and dusts and to prevent contact of the skin with vapours and dusts or solid material in the mass, the provision of screening and local exhaust ventilation is essential. Only as a last resort should personal protective equipment be introduced.

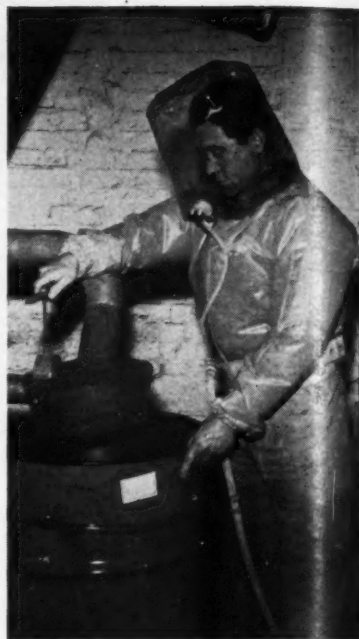
Sir Thomas Legge's third axiom stresses that we must protect the workman by means over which he can exercise no control. At present, this is not always possible, and we must at times resort to personal protective equipment such as respirators, gloves and goggles. While equipment for protection is available in almost every

contingency, we are faced with the problem of persuading the men to use it. Persuasion and discipline based on knowledge and understanding are means which have had success; but it is often a slow, uphill battle.

We come to the fourth Legge axiom and an extension of it. If a man is expected to work with hazardous materials (taking all the necessary precautions) in an efficient and safe way, he must know at least something of the hazards involved. He must understand the effect that the material and process can have on him if he does not work safely. He must have a clear, accurate job specification in which safety has been considered all the way through. He must be so well trained and disciplined that he adheres to all this.

### Maintenance

While such a system may cover routine day-to-day process work adequately, what happens when the plant is shut down for maintenance or when maintenance is required due to sudden failure of the plant? To cover these and other similar circumstances, management must lay down systems of work designed to protect both men and plant. There must be a procedure involving written certificates by which a plant is handed over from operating to maintenance personnel and back when the job is complete. The operating personnel must accept responsibility for handing over the plant in a safe condition or for specifying why and in what respects it is unsafe. The person in charge of the maintenance must then accept responsibility for the safety of his



Where it is impossible to protect the man in any other way protective equipment has to be used. This man is wearing a compressed air-fed half-suit

personnel and see that they work safely under the conditions prevailing. It is when such responsibility is not appreciated and accepted that some of the worst accidents occur.

The law, as embodied in the Factories Act, Chemical Works Regulations and other pertinent legislation, must be regarded as a minimum requirement. It is for this reason that the Association of British Chemical Manufacturers has undertaken various safety activities. Among documents published, its two volumes of 'Safety Rules for Use in a Chemical Works' form a sound foundation for safe practice in the industry, and the scheme for 'Marking Containers of Hazardous Chemicals', which is voluntarily implemented by its members, represents an important and practical advance in accident prevention.

### Hazards of a general nature

H.M. Chief Inspector of Factories some time ago raised a campaign against the five major causes of accidents: handling, falling, machinery, falling objects and hand tools. The chemical industry, having taken steps to obviate hazards specific to its products, has to deal with the same sort of incidents as anyone else. As already stated, the major accident causes in the chemical industry are precisely these and the steps taken are



Isolating the man from the hazard is the only sure way of attaining with certainty the ideal state of complete safety. Modern methods of remote control have made possible the design of fully automatic plants for the manufacture of such potentially hazardous products as explosives. The picture shows the control room of a Biazzi nitroglycerine plant

no different from those taken elsewhere by industries wishing to reduce their accident rate.

### Handling

Handling accidents can be prevented either by removing the need to handle goods or by training those who have to handle, how to do it safely. The first method is preferable, and not only from a safety standpoint, as handling adds nothing to the value of the goods being produced. Clearly this is a problem best tackled in the design stage of a new plant but where a process is installed into a building designed for something else, there may be no means of reducing the movement of work in process. Nonetheless it may be possible and economic to replace men with machines, to install rollers, or belts or fork-lift trucks—even a block and tackle is not to be despised. All methods of handling must be scrutinised, analysed and finally determined so that the worker can be taught how best to deal with his particular job. Any aid to handling is capable of reducing the accident rate providing that it is used correctly.

This applies to every kind of handling, from the lifting of large or awkward weights to the manipulation of hammers, spanners and screwdrivers.

### Falling

An astonishing number of people fall down each year and the causes are numerous. They may for convenience be listed under two main headings—environmental and personal. Environmental causes can be removed and to a large degree eliminated. Sound floors, well-maintained roads and paths and well-designed stairs with adequate landings and handrails, all well illuminated, will do much to remove the causes of falls. There is, however, always the man who trips over the proverbial matchstick or who turns his ankle on a non-existent stone. Constant reminders of the need to use suitable and properly repaired footwear will have some effect; continuous attention to the problem of spills will also bring results. It is only by such application to everyday occurrences that accidents are prevented. Good maintenance and good housekeeping are the foundations upon which the prevention of falls can be built.

### Machinery

Machinery plays a significant part in chemical production. All the recognised machinery hazards—in

running nips, belt drives, shafting, presses, guillotines and incorporators—can be found within the chemical industry. The difficulty lies in persuading chemical workers that these machines can operate safely and conform to the law. One press on its own seems much less dangerous than a whole battery. The chemical industry has developed guards for machinery used in laboratories so that at all stages processes can be safely operated. This is not the place to single out individuals or specific firms, but a great deal of pioneering work has been done by I.C.I. and their series of engineering codes and regulations, made available to the public through the Royal Society for the Prevention of Accidents, shows what can be done.

It is less easy perhaps to provide physical guards to deal with falling objects, although as anyone who watches demolition work in London will know, protection for the passer-by can be devised. Where men are at work above ground, working platforms and scaffolds should be constructed with proper hand rails, mid-rails and toe boards. The men themselves should have adequate containers for their implements and material, and there should be positive instruction and supervision to see that loose bits are safely stowed. Some plants make it a rule that anyone in an area in which overhead work is in progress shall wear a 'hard hat'. This should be more widely adopted, though it is

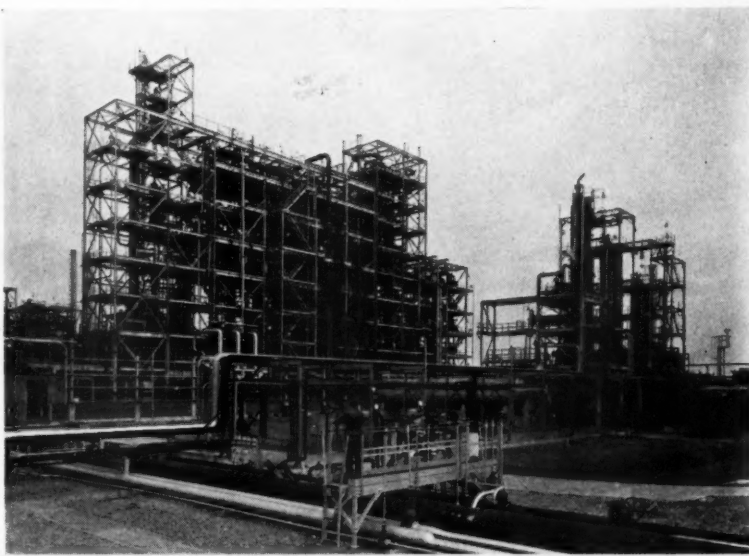
more important to prevent things falling rather than to give protection should they fall.

It is not only from heights, however, that things fall; many injuries arise because benches and platforms are untidy or because stillages and stock-piles are badly constructed. There is an overlap here with the hazards associated with handling, and correct methods of handling should include safe methods of stacking and storing.

### Hand tools

Finally, in this collection of culprits we have the use of hand tools. Few of us, for all the propaganda that has been issued, realise the full danger of mushroomed chisel heads or hammer heads. How many of us at home, let alone at work, have spanners with sprung jaws? Hand tools have to be maintained just as carefully as machinery; they have to be used for the job they were meant to do. To ensure that this is done is difficult, as every man thinks he knows how best to wield a hammer and to correct a tradesman is a task calling for diplomacy of a rare order. However, a great deal can be done by the regular inspection of tool kits and the insistence on correct usage to inculcate safe habits of working.

Having dealt with some of the minutiae of the Chief Inspector's big five, there should have become apparent a clear thread of principle. This is that in every case the responsibility for accident prevention rests



Whether men are working at low levels or high up, it is necessary to provide safe means of access and safe working conditions—properly designed permanent stairways with handrails, working platforms with toe-boards, mid-rails and handrails as brought out in this picture



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Table 1

Serial No.	Primary cause	National figure, %	Chemical industries, %
1	Machinery, etc. . . . .	18.6	8.0
2	Transport . . . . .	6.8	10.0
3	Fire and explosion of combustible materials . .	0.59	2.0
4	Explosions of pressure vessels, etc. . . . .	0.36	1.0
5	Electricity . . . . .	0.44	0.40
6	Poisoning and gassing . . . . .	0.08	0.89
7	Use of hand tools . . . . .	7.8	8.7
8	Falls of persons . . . . .	16.6	21.2
9	Striking, etc., other bodies . . . . .	8.0	7.9
10	Handling goods . . . . .	25.4	23.3
11	Falling objects . . . . .	8.5	6.1
12	Others . . . . .	6.8	10.5

Table 2

Serial	Industry	No. employed	Frequency rate
1	Scientific, surgical and photographic instruments, watches and clocks, etc. . . . .	30,600	0.91
2	Other electrical goods . . . . .	33,500	0.74
3	Aircraft manufacturing and repairing . . . .	105,800	0.84
4	Hosiery and other knitted goods . . . . .	10,800	0.65
5	Leather goods and fur . . . . .	1,600	0.96
6	Tailored and weatherproof outerwear . . . .	21,000	0.68
7	Other clothing, hats and millinery . . . . .	9,200	0.75
8	Footwear . . . . .	16,000	0.60
9	Printing, publishing of newspapers and periodicals . . . . .	22,400	0.91
10	Other printing, publishing, bookbinding, engraving, etc. . . . .	32,800	0.79
11	Laundries, dry cleaning, job dyeing, carpet beating, etc. . . . .	8,600	0.95

with management. Design, layout, maintenance, methods of work, training and discipline are all the duties of management. It is due to the desire of management to have freedom from accidents that safe working is accomplished. Without sincerity and wholehearted support from managers of all ranks, little or no progress can be made. It seems proper, therefore, to spend some little time on the means which have been used by some managers to achieve safe working in chemical plants.

### Design for safety

Firstly, it helps if the plant and process have been designed from the start to operate safely. If safety has been built into the job from the beginning, it should be possible to train all operators in methods of working which are considered to be safe. All operations, whether old or new, should be studied and analysed so that their hazards can be overcome. The desired method of carrying out the job should be written down to provide supervision with a training manual and the operator with a reference so that no one need be in any doubt as to the sequence of operations or the procedure.

This specification of the requirements and fulfilment of a job is in

our view one of the major factors in the safe operation of chemical plant. It may seem an enormous undertaking but there are ways of dividing the work by forming small committees (often including the man doing the job under review) which, by concentrating on a small section of a plant, can achieve fairly rapid results. This is not the task of a safety officer—nor necessarily of work study—but of all managers with such help that they care to enlist.

To run a chemical plant safely, the process must be worked out in the greatest detail, every known or possible hazard considered and then the process made as safe as possible. The rest lies in applying an enquiring mind to a variety of common situations to seek, find and finally to eliminate the pitfalls.

### Some statistics

Appendix VIII of the annual report of H.M. Chief Inspector of Factories, 1959, shows the incidence of reported accidents in manufacturing industries in relation to the estimated numbers of persons employed subject to the Factories Acts in that year.

Of the accident incidence rates per 1,000 employed persons under 'chemicals and allied industries' only four complete figures are available to work from. Using these figures, we find that

the rate for these four groups is 17.7.

The grand total on page 105 of the report gives a figure of 19. Although the footnote points out that the totals are not the full total of persons employed nor of accidents in factories subject to the Factories Acts, the two rates are considered to be comparable.

### Occurrence of accidents

Based on Appendix III to the report, a comparison is made in Table 1 of the occurrence of types of accidents expressed as percentages of all accidents reported to the Factory Department between the chemical industries and the national figure.

As might be expected, due to the particular hazards in chemical industries, serials 3, 4 and 6 compare unfavourably with the national figure. They do, however, represent only 3.89% of the total, whereas, of course, exposure to such risks is greater.

The more common types of accident due to falls and handling, as in other industries, account for a comparatively high proportion of all accidents.

### Frequency rates

Appendix IX to the report gives comparative accident frequency rates.

In 1959, with the exception of 'coke ovens and manufactured fuel', with a frequency rate of 4.01 for 5,700 employees, all other sections of chemical and allied industries have rates below the national average of 1.588. In 'chemicals and dyes', where 46% (74,600) of the total employees in this group work, the rate is no less than 0.97%, which is only improved on by the sections shown in Table 2.

### Safety award

The British Safety Council's 'Safety Award' is one of the highest industrial safety awards and only firms with an exceptionally high safety standard have a chance to qualify.

To gain the award, firms have had to beat the record set up by the most safety-conscious companies in their own particular industry.

Every accident where a worker has lost time is taken into consideration, and the firm's accident frequency rate (obtained from the number of man hours worked in a year compared with the number of lost-time accidents) is compared with the national average accident frequency rate for the particular industry. The national figures are prepared by the Ministry of Labour.

# Chemical Engineering Fundamentals-4

By K. L. Butcher,\* B.Sc., F.R.I.C., M.I.Chem.E.

*The last article in this series, which appeared in the October 1960 issue of CPE, ended with a brief discussion of entropy and methods of estimating changes in it, accompanying physical processes. In this article the final consideration of the general equation embodying the first and second laws of thermodynamics in differential forms is discussed, with particular reference to refrigeration and counter-current heat exchangers.*

THE equation  $dE = TdS - pdV$  applies to a fixed mass of substance in the absence of any work done on the substance by other than mechanical agencies. Now envisage other kinds of work being done which are electrical, chemical or physico-chemical in origin. Denote the net effect of these by  $\sum_i dw_i$  meaning the sum of increments due to the various effects of 'i' (which may, incidentally, include any kinetic energy imparted to the centre of gravity of the mass of substance)

$$dE = TdS - pdV + \sum_i dw_i$$

If the temperature and pressure of an operation on a system be kept constant, the system will obey the modified law

$$d(E + pV - TS) = \sum dw_i$$

Unless otherwise indicated, it will be assumed that the centre of gravity of the system is stationary.

## Gibbs free energy

The quantity  $(E + pV - TS)$  is conveniently represented by one symbol, i.e.  $G$ , and is called the Gibbs free energy of the system. Since this involves  $E$ , it is evident that the absolute value of  $G$  is not known, but changes in  $G$  can be measured. If  $G$  does change while temperature and pressure are being kept constant, it must be because of contributions of  $dw_i$ . If the interfacial area of a gram mole of a mixture of liquids is increased by  $dA$ , and  $\sigma$  is the interfacial tension (or surface free energy), then

$$(dG)_T = \sigma dA \quad \text{and} \quad (\Delta G)_T = \int (\sigma dA)$$

which may be  $\sigma A$  if  $\sigma$  is insensitive to area.

A system might be defined as known weights of copper, zinc, copper sulphate, zinc sulphate and water. When these are arranged in a suitable way, it is known that at constant pressure and temperature electrical energy may be withdrawn from the system. If one gram molecule of zinc sulphate is formed, then the electrical work obtained will be  $2\phi E$ , where  $\phi$  is Faraday's equivalent (coulombs per gram ion (univalent)) and  $E$  is the voltage (reversible) of the cell. Here  $\Delta G = -2\phi E$ , since  $\phi$ ,  $E$  are essentially positive members and the system has lost energy.

$G$  tends to diminish for a system undergoing spontaneous irreversible changes for the same reason that  $S$  increases. Equilibrium is reached when  $dG = 0$ , i.e. when  $G$  is a minimum, i.e. the system is capable of doing or receiving no more external work under the particular set of conditions reached.

The Gibbs free energy per mole of a given substance is the same for all parts of a system of which the component phases are in equilibrium.

Evaporation of a pure liquid at constant pressure and temperature in the absence of any other effects (i.e. when  $\sum dw_i = 0$ ) is a process leading to no change in the value of  $G$  per mole.

Such considerations form the basis of the phase rule, which may be summarised as follows.

## Phase rule

If there are  $P$  phases present, each being a region of homogeneous composition with characteristic properties, then there are  $(P - 1)$  equations for each independent substance present, stating that the free energy per mole of that substance is the same in each phase. If we suppose there are  $C$  independent substances, there are thus  $C(P - 1)$  such equations for equilibrium. In addition, the amounts of each substance in each phase must be defined. Taking the overall amounts of each phase as fixed (at unity), then fixing  $(C - 1)$  amounts of substances per phase will define the phase. There are  $P$  phases and therefore  $P(C - 1)$  such amounts. For the specification of the equilibrium ( $dG = 0$ ), the pressure and temperature must also be fixed (i.e. two more variables).

The total number of things to be arbitrarily fixed, less the number of independent equations relating these things to one another, gives the number of degrees of freedom  $F$  of the system

$$[P(C - 1) + 2] - C(P - 1) = F = C - P + 2$$

In chemical engineering work, separations of solutions into their component parts form an important part. It is important to know how little work need be expended, theoretically, to achieve a given separation. The 'unmixing' of two gases is a case in point.

If the operation is effected at constant temperature and pressure (in the overall sense), i.e. we start with a mixture of two moles of  $A$  and one mole of  $B$  at total pressure  $P_1$  and temperature  $T_1$ , and we finish with two moles of  $A$  at  $P_2$ ,  $T_2$  and one mole of  $B$  also at  $P_2$ ,  $T_2$ , then  $dw_i = dG$  for, say,  $dn$  moles of mixture, which may be regarded as  $dn = dn_A + dn_B$ . Since  $dG$  is made up of two parts, one associated with  $A$  and the other with  $B$ , let us suppose that

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$$\left(\frac{dG}{dn_A}\right)_{n_B} = \bar{G}_A \quad \left(\frac{dG}{dn_B}\right)_{n_A} = \bar{G}_B$$

Then a small addition of  $dn_A$  to a mixture of composition  $n_A + n_B$  will cause a change

$$dG = \left(\frac{dG}{dn_A}\right)_{n_B} \cdot dn_A$$

Similarly for the separate addition of  $dn_B$ . Thus  $dG = \bar{G}_A dn_A + \bar{G}_B dn_B$  for  $(dn_A + dn_B)$ .

Since removal is the opposite of addition the same type of argument holds. Furthermore, the removals may be arranged so that the increments of  $A$  in our case are always twice as large as those for  $B$ . Thus the remaining mixture would always be of the same composition as the starting material and ultimately  $\Delta G = \bar{G}_A \cdot n_A + \bar{G}_B \cdot n_B$  for whole separation.

All that is needed, therefore, is a means of evaluating

$$\bar{G}_A, \text{ i.e. } \left(\frac{dG}{dn_A}\right)_{n_B}$$

Since we are working at constant total pressure,  $dG \equiv d(E + PV - TS) \equiv d(H - TS)$ , then heat changes will be reflected in  $H$ . These are zero for mixing ideal gases or liquids. Thus  $dG = d(-TS)$  and as the temperature  $T_1$  is constant

$$dG = -T_1 dS = -T_1 \left[ \left(\frac{dS}{dn_A}\right)_{n_B} \cdot dn_A + \left(\frac{dS}{dn_B}\right)_{n_A} \cdot dn_B \right]$$

$$\text{The term } \left(\frac{dS}{dn_A}\right)_{n_B}$$

is easily calculated for it represents the entropy change per mole of substance  $A$  when one mole is transferred, isothermally and reversibly, from a state of partial pressure  $(p_A)_1 = p_1 \times \frac{2}{3}$  to a pressure  $(p_A)_2 = p_1$ . This we have seen to be

$$-R \log_e \frac{(p_A)_2}{(p_A)_1} = +R \log_e \frac{3}{2}$$

Similarly

$$\left(\frac{dS}{dn_B}\right)_{n_A} = -R \log_e \frac{(p_B)_2}{(p_B)_1} = +R \log_e \frac{3}{2}$$

Thus the minimum work required to separate three moles of mixture into two moles of pure  $A$  and one mole of pure  $B$  is

$$\begin{aligned} \Delta G &= -RT_1 [n_A \log_e \frac{3}{2} + n_B \log_e \frac{2}{3}] \\ &= -RT_1 [2 \log_e \frac{3}{2} + 1 \log_e \frac{2}{3}] = \text{positive.} \end{aligned}$$

Raoult's empirical law states that the partial pressure  $p_A$  of substance  $A$  over a solution is equal to the product of the mole fraction  $x_A$  of  $A$  [e.g.  $x_A = n_A/(n_A + n_B)$ ] with the vapour pressure  $P_A$  of pure  $A$  at the prevailing temperature  $p_A = x_A \cdot P_A$ .

If this law holds for a liquid mixture of  $A$  and  $B$  in which the ratio  $n_A/n_B = 2$ , say, as before, then it is easily shown that the same minimum work of separation would be required.

In practice, attempts to achieve separations with minimum theoretical work are made in the low-temperature separation processes for permanent gases. The cardinal practical points are as follows:

## Heat exchange

The smaller the local difference in temperature ( $T_1 - T_2$ ) between any streams exchanging heat  $dq$  the smaller the value of

$$(dq)_{ex} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

i.e. the smaller the increase in entropy. In general, this calls for maximising heat interchange area, or maximum number of distillation stages, and leads to such rules as 'contact hot with hot, cool with cool, condensing media with condensing media, dilute with dilute, concentrated with concentrated, etc.'

## Heat pumps

The usefulness of a given quantity of heat is connected with its temperature level. In particular the availability of latent heat of condensation in vapours may be increased by raising their pressure adiabatically. This causes a rise in temperature without the addition of heat as such and, therefore, the latent heat is upgraded from  $T_1$  to  $T_2$  and can be absorbed by systems having  $T < T_2$ .

The use of multiple-effect evaporation and of thermo-compressors for vapours in the concentration of liquid solutions is an application of the heat pump principle.

The example *par excellence* is, of course, the refrigerator in which the working substance, which is gaseous at normal temperature and pressure, may be fairly readily liquefied by compression and cooling with water at ordinary temperatures. If this liquid at ordinary temperature and high pressure is transferred (reversibly) to a system of substantially lower pressure it will commence to boil, utilising some of its own internal energy to supply heat of vaporisation until the temperature has fallen to the boiling point at the lower pressure. This may be  $-30^\circ\text{C}$ ., for instance. Any other liquid, say brine, warmer than  $-30^\circ\text{C}$ . may be made to supply heat to the boiling refrigerant. The refrigerant vapour is then recompressed, liquefied again, and so on.

If  $q_2$  is the heat absorbed per cycle by the boiling refrigerant at temperature  $T_2$ , with infinitesimally smaller temperature difference between refrigerant and brine, and if  $q_1$  is the heat removed per cycle from the hot refrigerant vapour by the condenser, at the condensing temperature  $T_1$ , then, provided all stages in the cycle are reversible,

$$\frac{q_2}{T_2} = \frac{q_1}{T_1}$$

Now  $q_2$  is called the refrigerating effect,  $q_1 - q_2 = w =$  work done by the compressor, and the coefficient of performance of the refrigerator is

$$\frac{q_2}{w} = \frac{T_2}{T_1 - T_2}$$

Thus for an expenditure of work  $w$  an amount of heat  $q_2$  is upgraded from  $T_2$  to  $T_1$ .

Since

$$w = \frac{T_1 - T_2}{T_2} \cdot q_2$$

it can be seen that, for a fixed load  $q_2$ , the work equivalent required to upgrade it is directly proportional to the upgrading  $T_1 - T_2$ . Putting in some figures for domestic heating, assuming that  $T_2 = 10^\circ\text{C} = 283^\circ\text{K}$ . and  $T_1 = 35^\circ\text{C} = 308^\circ\text{K}$ .,

$$w = \frac{25}{283} q_2 = 0.088 q_2$$

Thus less than 10% of the energy is required by this heat pump of that required by direct consumption of power (e.g. as electrical resistance heating) for space heating.

The practical difficulties are finding a steady source of heat at 10°C., say, and supplying the relatively large heat-transfer areas required for working with small temperature differences.

### Ideal process

The purpose in reviewing the elements of thermodynamics is to point the way to the realisation of the ideal process from the point of view of energy conservation. The strict adherence to the thermodynamic limits would in practice save the expenditure of much process energy but would be likely to require very large and complex plant, representing high investment costs.

In practice a compromise is sought and this, ideally, is arranged to minimise overall costs. We shall now go on to consider how to estimate the size of various types of chemical engineering equipment, designed to go some way towards satisfying the thermodynamic ideal, and it seems natural to begin with those processes involving the transfer of heat.

Generally speaking, the thermodynamic ideal of reversibility at every stage of an exchange operation is best approached by the employment of counter-current processes. If two streams of liquid *A* and *B* are available at weight rates of flow  $W_A$ ,  $W_B$ , with specific heats  $C_A$ ,  $C_B$  and temperatures  $T_A$  and  $T_B$ , by heat exchange  $T_A$  may be raised to  $T_A^1$  and  $T_B$  lowered to  $T_B^1$ , if  $T_B > T_A$ . The heat transferred is obviously  $W_A C_A (T_A^1 - T_A)$  or  $W_B C_B (T_B - T_B^1)$ , where the symbols represent inherently positive numbers. This amount of heat was originally at temperature  $T_B$  and has finally appeared at  $T_A^1$ . The rate of increase in entropy is thus

$$\int_{T_A}^{T_A^1} W_A C_A \frac{dT_A}{T_A} + \int_{T_B}^{T_B^1} W_B C_B \frac{dT_B}{T_B} \\ = W_A C_A \log_e \frac{T_A^1}{T_A} + W_B C_B \log_e \left[ 1 - \frac{W_A C_A}{W_B C_B} \left( \frac{T_A^1 - T_A}{T_B} \right) \right]$$

This is positive for all values of  $W_A C_A / W_B C_B$  when  $T_A^1 < T_B$ . Only for the case  $W_A C_A = W_B C_B$  and  $T_A^1 = T_B$  (i.e. infinite c.c. heat exchanger) is there no increase in entropy.

### Counter-current heat exchanger

Now consider the factors which determine the necessary area of a heat exchanger working on a strictly counter-current flow basis. First the general problem of heat conduction must be stated. This is as follows:

Heat flowing normally to an area  $A$  of a substance in which the temperature gradient (degrees per unit length) along the direction of flow is  $dT/dx$ , does so at a rate proportional to the temperature gradient and to the area  $A$ . If the heat flow rate  $q$  is considered to be positive when along the direction of increasing  $x$ , the temperature gradient must be inherently negative, so  $q = -k.A.dT/dx$ , in which the proportionality constant is called the thermal conductivity of the substance. It is usually assumed that there is no macroscopic motion of one part of the conducting substance relative to another part over the region in which  $dT/dx$  exists.

## The fifth article in this series, 'Chemical Engineering Fundamentals', will appear in the June issue of CHEMICAL & PROCESS ENGINEERING

Systems in which heat is flowing may be classified into two kinds. One in which, on the average, the temperature gradient at a given point remains at the same value over macroscopic periods of time. The other type of system is that in which this time independence of  $dT/dx$  is not true. The first case is called 'steady-state' heat flow, while the second is called 'unsteady state'.

Steady-state heat flow may be subdivided into two categories, one (a) in which the heat flux  $q/A$  is constant from point to point along the direction of flow, and the other (b) in which this is not so. Case (a) is that of the prismatic block of conductor perfectly insulated along its sides and conducting heat between its ends or the slab of 'infinite'  $A$  in proportion to  $x^2$ . Case (b) includes radial flow through cylindrical or spherical shapes, and also the case of uninsulated prisms (with ends at different but constant temperatures).

It is usual to deal with case (a) in introductory work, when more than one kind of material lies along the direction of flow and each presents an area  $A$  normal to it. Imagine three prisms of similar cross-section  $A$ , of materials  $k_1$ ,  $k_2$  and  $k_3$  conductivity. The steady flux passing through each substance in turn is

$$\frac{q}{A} = \frac{-dT}{dx/k} = \frac{T_1 - T_2}{x_1/k_1} = \frac{T_2 - T_3}{x_2/k_2} = \frac{T_3 - T_4}{x_3/k_3} \\ = \frac{T_1 - T_4}{x_1/k_1 + x_2/k_2 + x_3/k_3}$$

where  $T_1$  is the temperature of the surface at which heat is entering the combination.

The quantities  $x_1/k_1$ , etc., are obviously the counterparts of electrical resistance,  $(T_1 - T_4)$  that of voltage and  $q/A$  that of current density.

Where the cross-sectional area is a function of  $x$ , say  $A = f(x)$  in steady-state case (a), we have that the heat flow over the whole area is a constant

$$q = \frac{-dT}{dx/kf(x)} \text{ so that in this case } \int_{T_1}^{T_2} -dT = \frac{q}{k} \int_{x_1}^{x_2} \frac{dx}{f(x)}$$

or, in the case of the radial flow in the cylinder of length  $l$ , where  $A = f(x) = 2\pi lx$

$$T_1 - T_2 = \frac{q}{k2\pi l} \log \frac{x_2}{x_1}$$

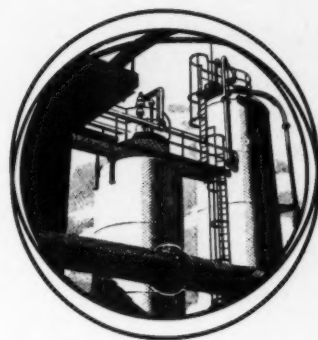
where  $x_2$  and  $x_1$  are the radii of the outer and inner surfaces. This has an interesting aspect, as  $x_1 \rightarrow 0$ . For a composite cylinder of three materials,  $k_1$ ,  $k_2$  and  $k_3$ , arranged concentrically

$$q = \frac{T_1 - T_2}{\log(x_3/x_1)/2\pi k_1 l} = \frac{T_2 - T_3}{\log(x_3/x_2)/2\pi k_2 l} = \frac{T_3 - T_4}{\log(x_4/x_3)/2\pi k_3 l} \\ = \frac{T_1 - T_4}{\frac{1}{2\pi l} \left[ \left( \frac{\log(x_2/x_1)}{k_1} \right) + \left( \frac{\log(x_3/x_2)}{k_2} \right) + \left( \frac{\log(x_4/x_3)}{k_3} \right) \right]}$$

# Materials of Construction for Chemical Plant

## REINFORCED PLASTICS

By K. Parvin,\* B.Sc., A.R.C.S., A.R.I.C.



*This is the eleventh article in our series 'Materials of Construction for Chemical Plant', which has included PVC, lead, nickel, stainless steel, graphite, polyolefines, copper, timber, titanium and aluminium. Reinforced plastics, first used in the United States some ten years ago, are finding wider use today. They consist of synthetic resins, usually of the thermosetting type, reinforced with fibrous materials.*

AS far as resins in reinforced plastics are concerned the main types used are unsaturated polyester resins, but epoxides, phenolic, furanes and silicones have all been employed, whilst amongst the reinforcement, glass-fibre in its various forms is pre-eminent but other fibres such as asbestos and Terylene can be employed.

### Glass-reinforced

The choice of reinforced plastics, especially glass-reinforced polyesters, is often indicated by consideration of both cost and performance. Although material costs are higher than for conventional materials, the advantages of being able to fabricate complex shapes without the assembly step often required with metal components are considerable. The costs of metal finishing, painting and maintenance operations are also obviated by their excellent finish and corrosion resistance.

Reinforced plastics have a high strength/weight ratio and can replace steel components of equal performance at one-third of weight. Their other physical advantages are a high impact strength, good dimensional stability, low heat conductivity, excellent elec-

trical insulation properties, good weathering and chemical resistance properties and good damping characteristics towards sound and drumming caused by vibration.

Another saving shown by reinforced plastics is the low-cost materials that can be used for moulds compared with the high tooling costs encountered in short to medium runs of metal pressings.

Table 1 shows the properties of certain laminate constructions compared with steel and aluminium.

### Glass-fibre reinforcements

Continuous glass filament is produced both from alkali (A) glass and alkali-free (E) glass. The strands of glass fibre, consisting usually of 204 filaments 0.0004 in. diam., are drawn together in the presence of a fibre size and these strands are used to make the common reinforcements, namely mat, rovings, roving cloth and woven fabrics.

Glass mat consists of chopped strands of glass fibre, randomly distributed and held together by a resin binder or alternatively mechanically bound by driving needles through the mat, causing some of the glass fibres

to act as stitching (needle loom or format). Chopped glass fibres are also used in dough moulding compounds.

Rovings are bundles of continuous filaments resembling untwisted rope and are available as 6, 12, 20, 30, 40 or 60 ends or strands. They can be used in this form or woven into heavy fabrics which are often used in conjunction with other forms of reinforcement.

Where high strength is required, glass fabrics are employed. These are made in plain, twill and satin weaves of various weights and are available either heat cleaned or with one of several finishes. These finishes are necessary because, to enable weaving to take place, a textile-type size is employed on the yarn which is incompatible with the resins employed. After weaving the size is removed by a washing or more frequently a heat-treating process and the finish, normally organo-chromium compounds or vinyl silane derivatives, applied.

The final form of glass utilised is surfacing tissue consisting of 0.012-in. tissue of finely bonded, fine glass fibres which is employed for surfacing mouldings.

### Resins

By far the most important type of resins used in the reinforced plastics industry are the unsaturated polyesters. These are produced by condensation of mixtures of saturated dibasic acids (e.g. phthalic) and  $\alpha\beta$  unsaturated acids (e.g. maleic) with one or more glycols. This condensation is carried out in an inert atmosphere at about 200°C. until the desired acid value, usually 30 to 40, is reached. The resultant viscous

\*Artrite Resins Ltd.



polyester is cooled and blended with a vinyl-type monomer such as styrene. An inhibitor to prevent premature gelation is included (see Fig. 1).

In the presence of peroxides—usually called catalysts but truly initiators—and heat, these resins are converted into rigid three-dimensional structures.

By the employment of peroxides in conjunction with accelerators or, more correctly, activators such as cobalt salts, this cross-linking can be made to take place at ambient temperature.

A wide range of resins with different properties can be obtained by alterations in the ratios of the unsaturated to saturated dibasic acids and variations in the acids, glycols and monomers. For example, by the use of chlorinated acids in place of phthalic acid, resins with self-extinguishing properties are obtained, which can be valuable in structures where there is a fire risk.

The basic polyesters themselves can be converted to formulated resins for special purposes such as gel coat resins, for gel coats in lay-up moulding, lay-up resins for moulding by the wet lay-up method and moulding resins for use in matched tool moulding. These formulated resins contain such additions as mineral fillers, thixotropic agents, pigments, etc., according to their intended uses.

The second largest group of resins used in reinforced plastics are the epoxide resins formed usually by the reaction of 2,2-di-(*p*-hydroxy phenyl) propane (*Bisphenol A*) and epichlorohydrin under alkaline conditions (see Fig. 2).

These can be converted to the infusible rigid, three-dimensional state by a number of different hardeners,

**Table 1. Properties of polyester glass laminates**

Property	Polyester resin +		Steel	Aluminium
	Glass cloth	Chopped strand mat		
Tensile strength, p.s.i. $\times 10^3$	30 to 55	10 to 25	60 to 70	10 to 35
Flexural strength, p.s.i. $\times 10^3$	40 to 70	15 to 35	60 to 65	10 to 25
Young's modulus, p.s.i. $\times 10^6$	2.5 to 3.5	0.8 to 1.8	30	10
Impact (edge notched), ft.lb./in.	12 to 25	5 to 20	45	20
Specific gravity .. ..	1.7 to 1.9	1.5 to 1.6	7.8	2.7
Thermal conductivity, B.T.U./sq.ft./hr./°F. .. ..	1.5 to 2.5	1.4 to 1.9	300	1,400
Coefficient of expansion, linear/°F. .. ..	5 to 6 $\times 10^{-6}$	10 to 18 $\times 10^{-6}$	6 to 7 $\times 10^{-6}$	12 to 13 $\times 10^{-6}$
Dielectric strength, V/mil ..	350 to 500	250 to 600	—	—
Insulation resistance, megohms	10 <sup>3</sup> to 10 <sup>5</sup>	10 <sup>3</sup> to 10 <sup>5</sup>	—	—
Dielectric constant .. ..	4.2 to 4.5	4.3 to 4.8	—	—
Loss factor .. ..	0.02 to 0.05	0.005 to 0.05	—	—
Glass content, % .. ..	60 to 65	30 to 40	Nil	Nil

e.g. amine, acid anhydrides, etc., to give a wide range of properties as regards temperature limitation, chemical resistance and so forth.

The final group of resins used in chemical engineering are the furanes, which are manufactured from furfuryl alcohol or furfuraldehyde and phenol. These resins are often used for resin cements or tank linings in view of their high chemical resistance.

#### Fabrications

The commonest methods of manufacturing glass-reinforced plastics are:

- (1) Lay-up moulding.
- (2) Matched tool moulding.
- (3) Spray moulding.

Of these, lay-up moulding is the most widely used technique and utilises a single mould on which glass fibres are laid up, bonded with resins and allowed to harden. The mould may be a male or female although, for structures such as chemical tanks, trays, etc., where a smooth inner surface is required, a male mould is usual.

The mould, which may be of wood, metal or reinforced plastic, is first coated with a release agent to allow ease of extraction. A gel coat resin, catalysed in accordance with the manufacturer's instructions, is then applied by brushing or spraying at approximately 1½ to 2 oz./sq.ft., i.e. a thickness of about 0.010 in. This gel coat gives a smooth glossy surface to the structure, hides the fibre pattern of the glass reinforcement and protects the glass/resin interface from chemical attack.

When the gel coat is sufficiently hard a heavy layer of lay-up resin, again catalysed according to manufacturer's instructions, is distributed over the area by brushing. The prepared pieces of mat are laid on and pressed into the resin so that the liquid soaks through. The laid-up mat is finally thoroughly rolled to consolidate the fibres, remove all the entrapped air and complete the wetting out. When the first layer of mat is fully wetted out, more resin is brushed on and the next layer of mat is laid up. This procedure is repeated until the correct amount of reinforcement has been applied.

After leaving for some time to allow

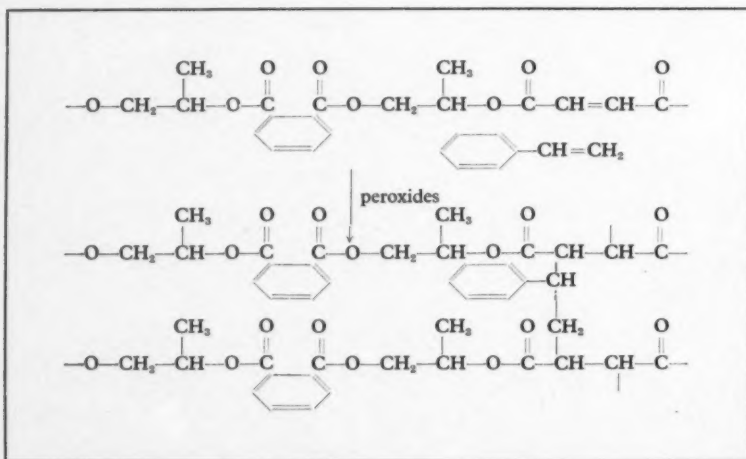


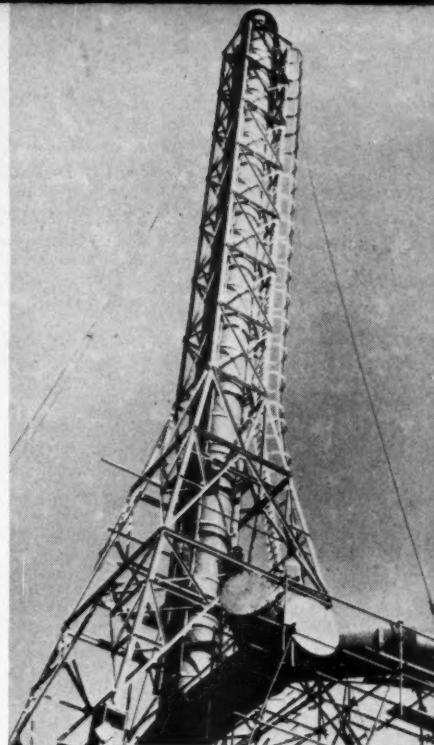
Fig. 1. Structure of liquid and cross-linked polypropylene glycol maleate/phthalate

# CAST IRON

Matched tool moulding derives its name from the fact that mouldings are produced in hydraulic presses using accurately machined male and female metal moulds which are heated. The glass reinforcement is placed in the tool as a dry glass-fibre preform made from chopped glass fibres which are bound with a resin. The catalysed,

For the production of ducting and pipes, wood or metal forms are wrapped with wet resin-impregnated fabric, tape or rovings. After the winding is complete, a sheet of cellulose film is applied under tension to consolidate the moulding and to give a reasonably smooth outer surface. After curing, the pipes are removed from the mandrel. Centrifugal casting can also be employed for the production of pipes, and in this method the reinforcement, normally glass mat, is placed inside a cylindrical mould, resin is evenly distributed and the heated mould rotated on rollers. Pipes produced by this technique have low glass contents but have good inner and outer surfaces.

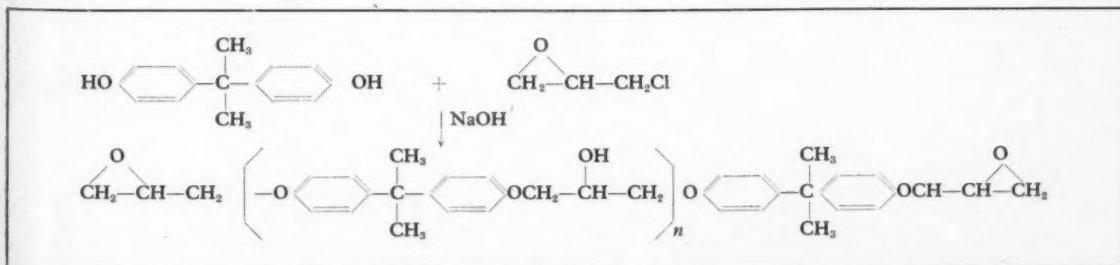
In general, polyester resins have good chemical resistance towards acids, salts, hydrocarbons, vegetable oils and many organic solvents. Their resistance to certain solvents, strong oxidising agents and alkalis is not so good, as can be seen from the chemical constitution, but progress is being made towards resins of increased resistance to alkalis.



This chimney is 106 ft. high, must withstand wind loads up to 90 m.p.h. and be resistant to strong acid vapours, which at the base of the chimney reach a temperature of 80°C.

The chemical resistance of epoxide depends to a large extent on the curing system used but, in general, they are more resistant to alkaline conditions than polyesters.

Tanks have been made for the storage of water, oil and chemicals and one manufacturer has replaced lead- and brick-lined tanks, used in



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the manufacture of alum, with G.R.P. tanks with the advantages of lower cost, lighter weight, longer life and lack of product contamination.

Mounted tanks have been made for the transportation of oils, chemicals and milk, whilst trays and tote boxes for the handling of chemicals have been moulded for the chemical, pharmaceutical and food industries. Large sectional tanks made from panels 4 ft. × 4 ft. × 3 in. of sizes from 6,000 to 1,000,000 gal. have been used by government departments and local authorities, whereas those supplied to industry are much smaller. One of these tanks has, for example, been used for the storage of an acid effluent from starch liquid at 50° to 60°C. The effluent contains SO<sub>2</sub> and albuminoids and has a pH of about 4. After three years' service this tank is still serviceable, but the metal downpipes and surrounding fittings require replacement every six months, due to corrosion.

Another tank has been in service for some years for the settling of granite sludge, which is both acidic and abrasive, without showing signs of deterioration.

Perhaps the most interest has been shown in tanks for the metal finishing and electroplating industries, where their lightness, ease of installation and corrosion resistance to acids show to advantage.

Glass-reinforced plastic covers are being used on sheet-steel pickling lines in place of steel covers, where acidic vapours and splashes from 25% sulphuric acid caused corrosion.

Large chemical tanks 20-ft. high and 8-ft. diam. have been made by the technique of laminating on to PVC for use with a concentrated bleaching chemical, and a similar construction has been used for process towers.

Machine guards are also frequently manufactured from G.R.P.

Pipework and ducting for the removal of corrosive vapours are also frequently made from polyester resins. Some large waste stacks have been fabricated which have shown longer life than conventional materials.

Filter press plates and frames have been moulded from glass-reinforced moulding compounds and, so far, failures have been only due to mechanical causes.

A more recent application has been the lining of large storage tanks some 60 ft. diam. by the spray moulding technique.

Polyester resins and glass have also been utilised for repairing holes in pipelines, storage vessels, etc. In

**Table 2. Chemical resistance of glass-reinforced polyester resins compared with other structural materials**

	Glass-reinforced polyester	Aluminium	Polyvinyl chloride	High-density polyethylene
Acetic acid (25%) ..	+	+	+	+
Aliphatic hydrocarbons ..	+	+	+	+
Aniline ..	—	+	—	—
Aromatic hydrocarbons ..	Varies with compounds	+	—	—
Ammonia ..	—	+	+	+
Brine ..	+	+	+	+
Caustic soda and caustic potash	—	—	—	+
Chlorinated solvents ..	Varies with compounds	+	—	—
Chromic acid (50%) ..	—	—	+	+
Citric acid (saturated solution)	+	+	+	+
Copper salts ..	+	—	+	+
Fatty acids ..	+	+	+	+
Formaldehyde (40%) ..	+	+	+	+
Glycols ..	+	+	+	+
Hydrochloric acid (10%) ..	+	—	+	+
Ketones ..	—	+	—	—
Mineral oils ..	+	+	+	+
Nitric acid (10%) ..	—	—	+	+
Phosphoric acid (50%) ..	+	—	+	+
Sodium carbonate ..	—	+	+	+
Sulphuric acid (50%) ..	+	—	+	+
Vegetable oils ..	+	+	+	+
Water ..	+	+	+	+

Key: + Resistant — Attacked

these instances the hole is sealed with a plug and layers of glass reinforcement with polyester resins are used to complete the seal.

#### The future

Research into polyester and other laminating resins is continually progressing and resins of greater chemical resistance and higher thermal stability are continually being developed.

One of the problems that remains to be solved is that of obtaining a resin which is resistant to alkalis. Such resins are available, but often their resistance to solvents is not as great

as that of resins which are not so resistance to alkalis. It may be that there will appear resins tailored for specific chemical resistance.

The maximum temperature resistance of polyester resins is about 250°C., but these resins have a number of disadvantages, viz. tendency to crazing, high price and the fact they cannot be cured at ambient temperatures. If these resins can be improved to overcome these difficulties, glass-reinforced plastics could move into other fields where temperatures are the limiting factor at the moment.



Washing tank

[Courtesy: Manmills Plastics Ltd.]



# PUMPING

By A. Flindle, M.I.Mech.E.

*The importance of pumps in the chemical industry cannot be overstressed. It is little wonder, therefore, that there is an ever-increasing demand for such pumps which have to resist increasingly stringent conditions. This review describes some recent developments in the design of pumps with particular reference to the chemical and process industries.*

It must be appreciated that there has always been a large number of manufacturers supplying water pumps to industry; the ranges of chemical pumps until recently, however, were limited to those which were constructed of special materials such as ebonite, stoneware and plastics. Indeed, until only a few years ago a pump made of materials other than cast iron or bronze was considered a 'special' pump. Although most textbooks dealing with pumps do not discuss the design of pumps for the chemical industry, it is quite wrong to assume that a design developed for pumping water can be made of a different material and therefore suitably applied for pumping corrosive chemicals. The following points may be generally considered the main criteria used when selecting a pump for the chemical and process industries:

- (1) Simplicity of design
- (2) Suitable materials of construction
- (3) Minimum of leakage points
- (4) Capability of dealing with vapour and solid entrained in the liquid.

The first criterion is postulated in order to attain a greater economy; if a maximum number of parts are interchangeable this will reduce stocking of spares and make all parts easily accessible.

## Corrosion

When selecting a material of construction it must be appreciated that corrosion problems in pumps are often of a complex nature. Thus the liquid pumped, as well as the concentration of oxidising agents such as air and steam, must be taken into account. A primary factor controlling corrosion is the tendency of the metals to dissolve electrolytically in the solution pumped. For this reason homogeneity

of the surface is of great importance, i.e. cracks, scratches and rough machining parts should be avoided.

The ability of some metals to generate a self-protecting film is therefore of great value. Very useful guides are the pH and galvanic scales which give a first indication of metals not to be used. Only metals which lie close to one another on the galvanic scale may be used safely and dissimilar metals should, if possible, be insulated and the less noble metal suitably coated. Aeration of the liquid should be prevented, or at least limited, and the hydraulic phenomena of cavitation entirely avoided.

## Minimum leakage

To minimise the maintenance of joints, the wetted casing should be reduced to be simple and circular. A difficult point for the chemical engineer is the method of sealing around the rotating and reciprocating shaft. Recently increasing attention has been paid to this point and many special designs of chemical pumps have been evolved to improve or eliminate the shaft seal.

## New diaphragms

Attempts to avoid both stuffing boxes and mechanical seals have led to the development of the glandless pump, which can be either horizontal or vertical. The advantage of this pump is that it has no stuffing box or mechanical seals but some other device to minimise leakage conditions, such as diaphragms.

A new method of diaphragm construction was recently developed by Girdlestone Pumps Ltd., which considerably lengthens the life of the diaphragm. It consists of three layers of rubber of approximately the same

thickness bonded together. The central layer has a higher hardness than the outer two layers. The principal advantages are that the diaphragm is more flexible and, as there are no non-elastic reinforcing inserts, deterioration of the rubber by internal heating is eliminated.

## Double volute pumps

Many installations require pumps that need minimum service and must be simple in design. Because of these requirements there is an increasing tendency to popularise double-volute single-stage pumps, and experience has shown that any additional cost for these units as compared with the straightforward conventional volute pump is amply repaid in working life—especially in those cases where long hours of service are demanded and the working pressure is relatively high. The double volute is introduced for the purpose of eliminating the unbalanced radial pressure forces which are known to exist in the conventional volute pump. These forces vary in intensity and they are more evident when the pumps are called upon to operate under conditions that are not conducive to efficiency.

Another feature tending to popularise the double-volute pump is the particular benefit found in those instances where mechanical seals are required in preference to soft-packed stuffing boxes, the reason being that, whilst the turns of soft packing play a supporting role as a steady bearing in the straightforward volute pump, similar co-operation from mechanical seals cannot be expected and the effect of unbalanced radial forces becomes rather more pronounced and irritating when high-capacity or high-head continuous service pumps are in use.



'Metastream' flexible metallic coupling

Modern tendency in pumping practice is to standardise where possible on one pump size and achieve from it maximum head/quantity variation so that users may install an absolute minimum number of sizes of pump. In these cases the introduction of a diffuser instead of the double volute not only compensates for unbalanced forces but also gives maximum efficiencies over a fairly wide selection of different impellers used in the same basic casing.

In this case any extra additional cost is more than offset through the advantage gained by flexibility of duty selection and small quantity of spares to be carried. Thus 'in-line' vertical diffuser pumps have the suction and discharge branches arranged so that the pump actually fits into the pipeline as simply as an ordinary pipe section. Their driving motors are arranged immediately above them and the impeller is mounted upon the motor shaft extension so that the initial cost is considerably reduced by the elimination of baseplate and coupling; there is also appreciable saving in floor space.

Another type of pump, the *Easiclean*, made by Plenty & Son Ltd., can also be connected into a pipeline. This is a self-priming pump which can handle a wide range of chemical and pharmaceutical products, from light spirits to acid sludge, hair cream and tooth paste. Its capacity depends on the viscosity of the fluid to be handled; standard units will handle between 33 and 90 gal./min. when running on medium viscosity. These pumps are made with stainless-steel

bodies, rotors and shafts, together with a special inert-bonded material which is used for the liner, bearings and blades.

### Reciprocating pump

For the controlled transfer of viscous fluids in chemical processes Ormerod Engineers Ltd. have designed the *QP-Shirley* metering pump which is basically a simple reciprocating plunger type with mechanically operated mushroom inlet and outlet valves. The plunger is not driven by a crank but is moved backwards and forwards by a cam which allows a dwell period at each end of the stroke. Another cam controls the opening and closing of the inlet and outlet valves and is so arranged that this opening and closing takes place during the dwell period at either end of the piston stroke.

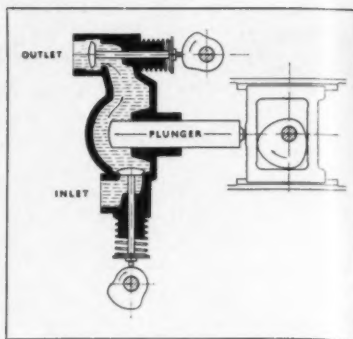
The inlet and outlet ports are of large area, the outlet being directly over the inlet and at the highest point of the pump chamber so that any air initially entrapped is expelled before the liquid. The valve timing is such that inlet and outlet valves can never be open together, hence there is no opportunity for forward or backward flow of liquid unrelated to the motion of the pump plunger.

### Self-priming centrifugal pump

Self-priming centrifugal pumps are centrifugal pumps which have the dual ability to pump, under vacuum, either liquid or gas. Primarily, pumps of this type are liquid-handling pumps, their ability to pump gas being a supplementary characteristic. The most frequent use of such pumps is for lifting liquids from a level below the pump; the vertical distance through which such a pump can lift depends upon several factors such as the specific gravity of the liquid, its temperature and vapour pressure. British LaBour Pump Co. UPL and UHL pumps have a suction lift equivalent to 20 ft. of cold water. Gland trouble is minimised, as there is a negative pressure at the impeller centre and therefore no tendency to leak outwards at the gland.

In the process industries there are many other applications for these pumps such as unloading of tank cars, evaporator and vacuum filter service, handling volatile liquids, contact tower service and a variety of transfer applications.

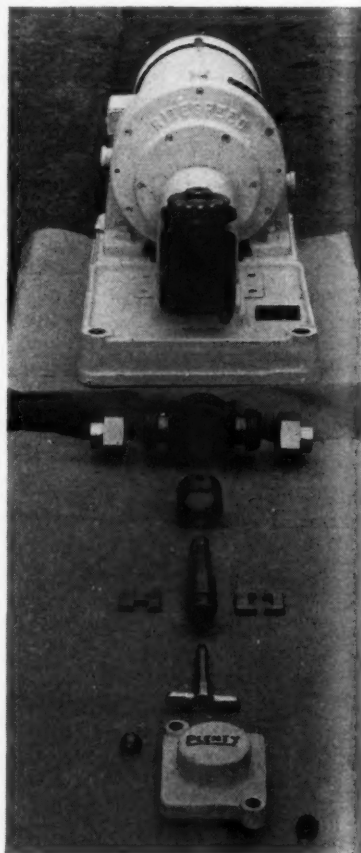
Their capacities are up to 1,300 g.p.m. and are supplied in a large number of corrosion-resistant materials. They can handle suspensions containing up to 40% solids contents.



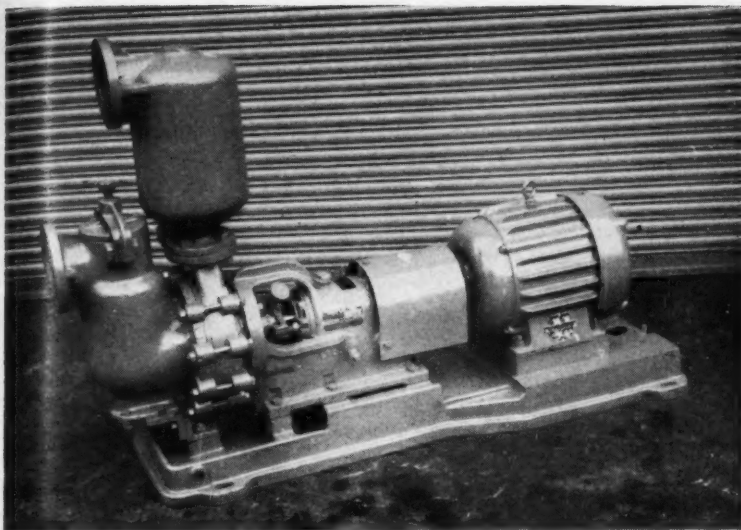
Section of 'QP Shirley' metering pump

### Pumping corrosive liquids

For handling corrosive and highly volatile liquids it is necessary to have a pump with self-priming characteristics; a particular example of such a pump is the Girdlestone *Autostart* centrifugal pump which works on the recirculation principle, the main advantage being that in this particular case all the liquid is held below the centreline of the pump and it is therefore



Plenty size ML 'Universal Easiclean' pump showing simplicity of dismantling



LaBour horizontal self-priming centrifugal pump

unnecessary to have a non-return valve and check flap fitted in the suction side of the pump.

The pump has been successfully employed in many applications, as for example in the handling of ether with a suction lift of 10 to 12 ft., and in the extraction of sludge from the bottom of a still under self-priming conditions.

These pumps, manufactured in a wide range of materials of construction are at present available for capacities of 630 to 1,550 gal./min. against a total head from all causes of 5 ft. Heads up to 90 ft. are also possible at reduced capacities down to 200 gal./min.

An end suction 2 to 2½-in. centrifugal pump has been specially designed by Lee Howl & Co. for the handling of corrosive liquids, *i.e.* sulphuric acid at any temperature or concentration, nitric acid, acetic, formic, phosphoric acid and many others. No wear rings are fitted, the impeller running clearance being generous, thereby avoiding rapid loss in pumping efficiency from wear and corrosion. The various components in contact with the acid are made of silicon iron.

To handle comparatively small quantities of acids of corrosive liquors, L. A. Mitchell Ltd. have designed the *Simplex* bellows pump. The pumping action is achieved by the deflection of a closed PTFE bellows which is actuated by a reciprocating diaphragm pressurising an oil reservoir.

The acid or liquid end and the bellows are the only parts of the pump in contact with the liquor being pumped. Liquid ends can be supplied in a variety of materials such as cast

iron, stainless steel, *Monel*, PVC, PTFE or chemical stoneware, according to the liquor to be pumped.

For filtration duties required in the clarification of industrial and pharmaceutical chemicals, uniform delivery under varying heads or pressures is important. For duties of this nature, especially when involving corrosive chemicals, the materials of construction have to be carefully selected. A filtration pump made by Mono Pumps Ltd. is ebonite lined with *Langalloy* and *Corronel* rotating parts; the pressure head developed is independent of pump speed and therefore a suitable speed can be chosen to relate the pump capacity to the flow rate of the production cycle. This pump can handle a thick suspension of sodium chloride and hydrochloric acid and

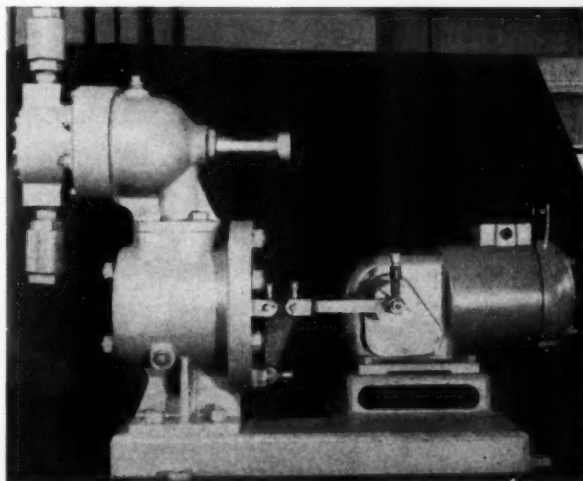
can deliver to a filter press at a maximum pressure of 40 p.s.i.

### Flexible coupling

There are obvious signs, judging from the foregoing descriptions, that many leading pump manufacturers have been busy on new developments and designs during the past two or three years to meet the growing needs for pumps to deal with more arduous conditions of service with a minimum of maintenance and at competitive prices. New problems are constantly facing the pump designer and his work is never finished.

Emphasis in this review has been on the pump itself, the driving unit such as a motor and, above all, a flexible coupling connecting the two are also of great importance. Regarding the latter, it is a common fallacy that connecting two shafts together is relatively simple, but very often this is not the case as, for example, where high service temperatures are encountered, resulting in shaft misalignments and relative axial displacement of the shafts. Consequently, it has become necessary to use flexible couplings which would accommodate such conditions, and various types of coupling have been in use for many years.

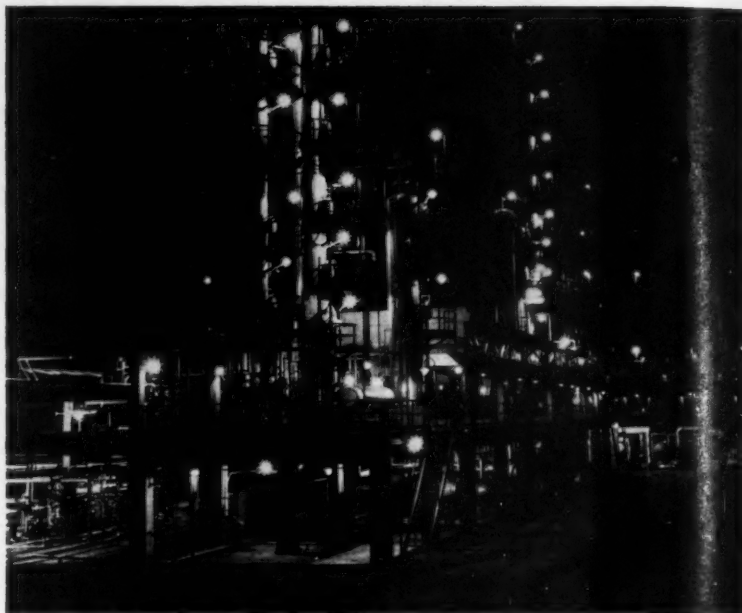
Several years ago an all-metal flexible power transmission coupling called *Metastream*, made by Metaducts Ltd., was produced. This coupling has been extensively applied in the petroleum and chemical industries. It is capable of accommodating reasonably wide limits of lateral and/or axial misalignment together with free axial displacement under conditions of full torque. It should be noted that this coupling is both torsionally rigid and reversible in rotation.



Mitchell 'Simplex' bellows pump



# IRELAND'S CHEMICAL INDUSTRY



A night view of the 'Powerformer' at the Irish Refining Co., Whitegate

By I. L. Hepner, Ph.D., A.M.I.Chem.E.

IRELAND has served as the agricultural farmyard of Great Britain for so long', said several Irish Government officials to me recently, 'that she has a long way to catch up in order to transform herself into even a partially industrialised community'. It would be accurate to comment that one of the peculiar side-effects of the industrial revolution, which started in England, was to discourage similar industrial enterprise in Ireland, because it was considerably cheaper in the 19th century to import industrial equipment and chemicals from Merseyside or Clydeside across the Irish Channel. Until the 20th century, therefore, little serious effort was made to create an Irish chemical industry.

Nevertheless, this impediment has not altogether been to Ireland's disadvantage since she is now in a position to plan an integrated chemical industry without being tied to out-moded 19th-century industrial traditions. The results to date are evidence of this; the small Irish chemical industry is a fertile seed for what may become in the next generation a flourishing chemical industry.

Naturally, the prime consideration when planning chemical process industries is to utilise as much as possible any indigenous raw materials. Ireland

*A recent tour of several representative branches of Ireland's chemical industry has convinced the author that, although small at present, this particular industry shows great promise of considerable expansion during the next few years.*

unfortunately has been none too lavishly endowed by nature with raw materials; apart from various mineral ores practically all chemical raw materials have to be imported. The most abundant raw material in Ireland is the land, and most government planners have been supporting the view that any industrial development should be tied, wherever possible, to agriculture.

## Sugar industry

One such example is the sugar industry. Up to 1934 there was no beet sugar grown in Ireland. The government then initiated, with Belgian assistance, an extensive beet-growing programme and built four sugar refineries. As a result the amount of sugar beet processed during

1959 amounted to 128,791 tons. The sugar refineries of the Irish Sugar Co. are comparatively modern; they were constructed shortly before the second world war by a Czech-German company, who were specialists in sugar technology.

The following process is carried out at the Marlow sugar refinery. The sugar is extracted from the beet by shredding the beet into thin chips (cossettes) and passing these into a continuous diffuser where sugar is extracted by means of hot water. This continuous diffuser is a revolving cylindrical drum inside which are welded two distinct helical strips forming a double-threaded screw. Thus these two helical strips form the sides of a double series of compartments. The helical strips have rectangular openings in the centre of which are chutes. Before being carried into the fixed compartment, the cossettes are weighed on an automatic scale, after which they are dropped into a scalding trough where they are scattered into a current of hot, raw juice (at a temperature of 90° to 95°C.) which conveys the chips into the fixed-end compartment of the drum.

The hot juice is separated from the chips by passing through a curved screen covering the lower periphery

of the fixed-end compartment, whilst the chips are lifted up by two longer grids to be introduced into the drum through the first two chutes.

The raw juice produced by the apparatus also flows through the curved screen and the mixture of the two juices passes into a reservoir from which the necessary quantity of juice for the trough is continuously withdrawn by means of a circulation pump. The excess juice corresponding to the quantity produced by the apparatus is taken out of the same reservoir by an exhausting pump, depulped in a juice screening apparatus, measured and directed towards the carbonators where carbon dioxide is added to precipitate impurities in the juice. These impurities are then separated by filtration and the clarified juice is decolourised and passed into the quadruple-effect evaporator where the sugar content of the liquor is increased from 16 to 60% total solids.

The Irish Sugar Co. is not exclusively concerned with the refining of beet sugar, but, in order to aid agriculture, they are also advising the farmer on soil drainage, supplying beet seed at very low prices, manufacturing special beet fertiliser and ground limestone. In addition, they have recently designed a special beet harvester which can rapidly and effectively harvest beet crops. This comprehensive programme provides continuous employment for the refinery operators who were previously only employed for the duration of the rather short harvesting season (from November to January).

### Food processing

More ambitious plans in connection with food processing were recently initiated. It may be recalled that several years ago research carried out by the Ministry of Agriculture, Fisheries and Food at Aberdeen showed that food could be processed by freeze drying and be comparable with deep-frozen food not only in quality but also in cost to the consumer. Since the end of the last war, of course, freeze drying has been used extensively in the pharmaceutical industry (blood plasma is the best example) and the advantages claimed for freeze-dried food are very long storage life and considerable reduction in bulk weight. The Irish Sugar Co. thereupon commissioned the first commercial accelerated freeze-drying plant which is now under construction at their Mallow refinery and is expected to be completed during the next few months.<sup>1</sup> Although the capacity of

the Mallow A.F.D. plant does not exceed pilot size, it is hoped that this will be the first step in creating a food processing industry which would aim at the considerable export markets in Africa and Latin America. This is another example of harnessing the chemical industry to the land.

### Oil refinery

Apart from these agriculture-based industries, Ireland has one oil refinery in Whitegate, Co. Cork. It is certainly one of the world's most scenically enchanting oil refineries, situated in the vicinity of Cork Harbour with excellent deep-harbour facilities where tankers up to 35,000 tons can deliver the crude oil (mainly from the Middle East).

The refinery, opened in 1959, is owned by the Irish Refining Co. Ltd., which was established as a consortium of three companies, Esso Petroleum Co., Shell-Mex & B.P., and the California Texas Oil Corp., who were convinced that consumption of oil products in Ireland has already attained a level which would economically justify such a refinery. Since it only serves the Irish market, it is rather small in capacity, its present output being in the region of 30,000 to 40,000 bbl./day.

The refinery operation is carried out as follows: Crude oil is passed into the first fractionating tower where it is separated into four main fractions: an overhead distillate, a side-stream distillate, a gas-oil distillate and the residual fuel oil. Both the overhead and the side-stream distillates are then treated in a fractionating tower to remove light gases.

An intermediate fraction between the overhead distillate and the gas-oil distillate from the tower is used as feed stock for the *Powerformer*, which is a catalytic reforming unit. The *Powerformer* consists of a series of five reactors containing the catalyst pellets of platinum on alumina base. Only four out of five reactors are in use, since the catalyst becomes charred after some time. Regeneration of catalyst has to take place in each reactor intermittently.

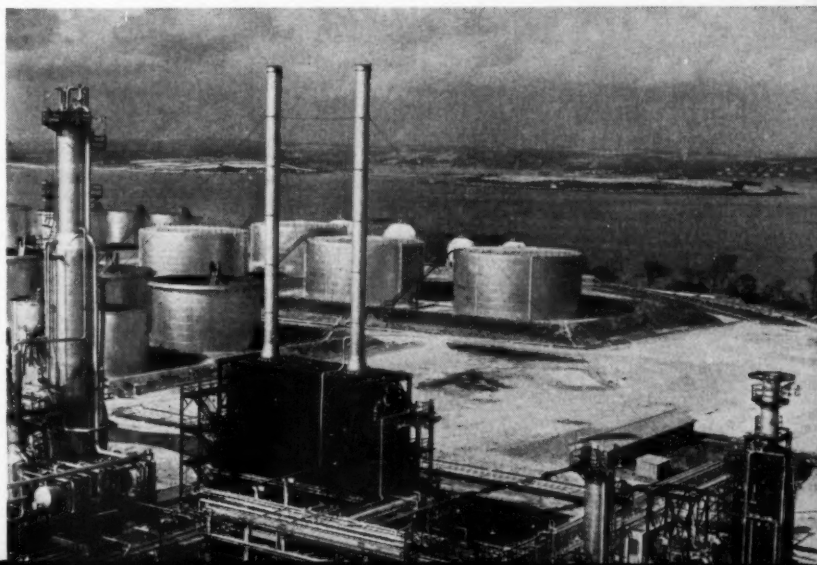
### 'Powerformer'

The feed stock to the *Powerformer* is first passed into a heating furnace where it is vaporised under pressure and then enters the first reactor. Vapours passing out of the first reactor are then reheated in a reheating furnace (to compensate for any temperature loss entailed in the reactor). They are then passed into the second reactor and once more through a reheating furnace into the third reactor, then again through a reheater into the fourth reactor.

The vapours are finally condensed, the pressure being reduced in stages by means of suitable reducing valves. In this way reformed gasoline is separated from propane and butane fractions. The propane and butane from the *Powerformer* and from the light overhead distillate are separated in two fractionating columns—the depropaniser and debutaniser. As liquefied petroleum gases they are sent to bottling stations all over the country where they are sold to domestic consumers for heating and cooking.

The gas-oil distillate is passed into a *Hydrofiner* where sulphur is re-

General view of the refinery at Whitegate showing the crude pipestill furnaces and fractionating tower (left) and the 'Hydrofiner' furnace, reactor, fractionator and the stripper on the right. Product storage tanks are in the background



moved and the product is then distilled to make turbo-jet fuel and diesel oil.

The residual fuel oil is supplied for bunkering and for industrial heating. Lighter fuel oils are also made by cutting fuel oil with the lighter gas oil.

A novel feature at the refinery is the use of air cooling instead of the vast quantities of water normally used. This is a comparatively new technique, in fact Whitegate is the first completely air-cooled refinery in the world.

The primary aim of the Whitegate refinery—and this has now been achieved—has been the supply of petroleum fuels for Irish home requirements. The refinery must now look into the future; inevitably it takes considerable interest in fostering an Irish petro-chemical industry. In this way there may be a ready market for the lighter hydrocarbons, as well as incentive to expand overall production (there is ample land at Whitegate for any expansion).

For any petro-chemical industry to succeed it would have to be located near Whitegate so that products could be piped 'over the fence', a common procedure at several other British refineries. Upon such potential development is centred the future, not only of Ireland's only refinery but also of the Irish chemical industry. If investors of sufficient foresight could be found to take advantage of the Irish government's financial inducements and build a petro-chemical industry, Cork may yet become as important a centre of the chemical industry as other ports in the U.K.

### Peat from bogs

Apart from a small quantity of anthracite, Ireland's only indigenous fuel resources are peat (or turf, as it is called in Ireland and all over Europe). The peat is reclaimed from bogs, which are a characteristic feature of the Irish landscape. It has been calculated that one-seventh of the area of Ireland is bogland. Throughout the centuries these great wastelands have provided fuel for the farmers living in their vicinity; however, only the perimeter of the bogs was used. The interior was, until not long ago, impenetrable because of the high water content of the bogs (93%). Hence the main problem was to convert this very low-grade but abundant material to useful ends by removing the water economically (and, incidentally, making the land arable).

Bord na Mona, the Irish Peat Board, was established by the Irish

Parliament in 1946 to carry out the task of producing fuel from the bogs. Two main methods at present used by the Board for the production of fuel are:

(a) Machined sod peat process.

(b) Milled peat process.

Bord na Mona's objective is to produce one million tons of sod peat and half a million tons of milled peat. The sod peat is used partly for electricity generating stations and partly for domestic and industrial consumption, whereas the milled peat (except for a relatively small quantity at present converted into briquettes) is used only for power stations.

### Peat as fuel

The Bord's research station is situated in what used to be a former British Army barracks in Newbridge, Co. Kildare. A small energetic team of chemists, fuel technologists and agronomists are working there on new outlets for peat; its potential uses range over many spheres including agriculture, pharmaceuticals and chemical processing—nevertheless, its most important application will always be as a fuel. It is in connection with its use as a cheap economic fuel that the Bord's research staff are very optimistic. Despite the fact that peat has a lower calorific value (about 6,500 B.T.U./lb.) and greater bulk compared with other fuels, it still has considerable advantages over them. It is more reactive than coal. Its ignition temperature is the lowest of any solid fuel and therefore fresh peat burns as soon as it is thrown on the fire. Peat is also non-caking and has a low combustion temperature, the heat released being spread over a large volume of gas. Since it has a high volatile matter content (67%), peat can be burned with a low excess of air; in properly designed furnaces the efficiency can be very high.

It is with efficient design of peat-fired boilers that the Newbridge fuel technologists are primarily engaged. A modern form of furnace designed

by the Bord recently is the *Mona* jet burner. This is a grateless burner which operates on the down-jet system of air supply that cannot be duplicated by natural draught. The air jet is directed downwards onto the fuel bed so that it penetrates sufficiently to create combustion and also mixes with the volatiles to complete combustion. Thus extremely turbulent conditions can be generated inside the burner and complete combustion will take place with minimum of air.

As a result of such an integrated fuel programme, Irish industry is slowly adapting peat as a fuel for firing boilers, furnaces and even for the generation of electricity. There are several peat-fired electricity power stations throughout the country already. One of the largest, the Allenwood Power Station, Co. Kildare, is designed for a consumption of 180,000 tons p.a. of peat, giving an output of 135 million units of electricity.

A chemical processing industry based on peat is within the realms of possibility during the next generation. Extensive work is being carried out at present in connection with the total gasification of peat. Similar work is also undertaken in Germany, Scotland, Finland and the U.S.S.R.; perhaps the future of peat will be as a source of synthesis gas for ammonia and hydrocarbons (based on Fischer-Tropsch synthesis). As in the case of a petro-chemical industry, much will depend on the availability of foreign capital to invest in such long-term projects.

### Standards Institute

The hallmark of any young country seriously contemplating industrialisation is a good Standards Institute. In Ireland the Institute for Industrial Research and Standards, located in Dublin, combines the activities of a standards institute with an industrial research laboratory. Its director, Mr. D. T. Flood, describes the research activities of his institute more as 'trouble-shooting' than pure research; it aims to help Irish industry overcome technical day-to-day difficulties. The chemical industry in Ireland is too small to engage in fundamental research work of any magnitude and the Institute must therefore be ready to develop projects which it feels would be of ultimate benefit to industry. With this in mind, new premises were recently erected to house a small unit operations chemical engineering section.

Apart from this, the Institute also designs standards to suit the need of

**£ s d**

**CHEMICAL PLANT COSTS**

Cost indices for the month of February 1961 are as follows:

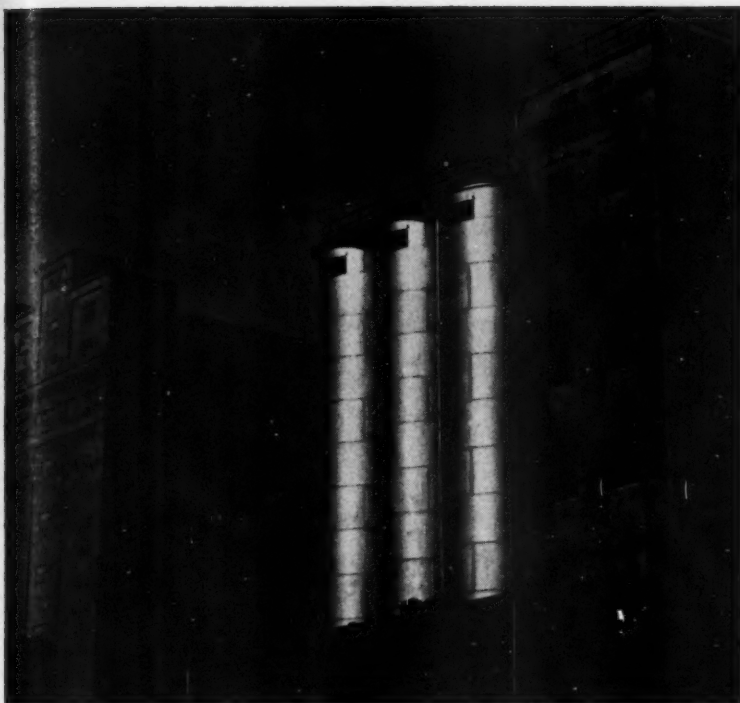
Plant Construction Index: 182.9

Equipment Cost Index: 173.1

(June 1949 = 100)

**£ s d**





[Courtesy: Irish Department of External Affairs]

Much of Ireland's chemical industry involves food processing such as the flour mill of the Dublin Port Milling Co.

Irish manufacturers; in most cases existing British and European standards suffice but often new products are manufactured locally for which non-Irish standards are neither suitable nor available.

lishing manufacturing industries in Ireland. Special financial advantages are granted to foreign firms, including outright non-repayable grants for new industries—up to the full cost of factory buildings, up to 50% of the

cost of plant and machinery, and tax exemption on profits earned by exporting manufactured goods. This scheme has already attracted many firms from as far apart as America and Japan.

From a brief tour of several representative Irish industries I feel convinced that these ambitious programmes will succeed in partially transforming Ireland into an industrial community. Much will depend upon whether the disastrous efflux of skilled young people can be arrested; the Irish youth must be made to feel that their country can offer them decent prospects for the future.

In addition, technological education must be expanded. At present there is too much emphasis at the universities on pure fundamental science and too few departments of engineering. No underdeveloped country can expect to become technologically self-sufficient if it does not attempt to train its young people in modern technology. The Irish government might be well advised to examine the educational structure prevalent in Holland and Denmark — small agricultural countries that have a superb standard of higher technological education.

A combination of government-sponsored industrial development placed against a wider framework of higher technological education may yet create a Scandinavian standard of living in the Emerald Isle.

#### REFERENCE

<sup>1</sup>*Food Manufacture*, 1961, **36** (2), 56, 60.

#### Conclusions

Industrial expansion in the Republic of Ireland has entered a new critical phase; no longer is Ireland satisfied to remain the backward, agricultural small brother of Great Britain. Her volume of industrial production has more than trebled since 1926 and the numbers engaged in industry have more than doubled—the gross industrial production in 1958 amounted to £414 million. Proportionately, the chemical industry has also increased, but perhaps not at the same rate. The following chemicals are at present produced in Ireland: sulphuric acid, soap, solvents, glycerine, benzole, naphtha, acetylene, fertilisers, carbon dioxide and pitch.

The Irish government is keenly interested in inducing foreign firms to build factories in Ireland. To this end they have established the Industrial Development Authority, which is specifically charged with the task of assisting industrialists in other countries who may be interested in estab-



[Courtesy: Irish Tourist Association]

One of the few mineral deposits in Ireland is barytes. The picture shows a barytes mine in Co. Sligo

# Personal Paragraphs



Mr. Joseph W. Smith



Mr. Harry Williamson



Dr. James Marten

★ **Mr. Harry Williamson**, managing director of Fischer & Porter Ltd., has also been appointed managing director of the Dutch company Fischer & Porter (N.V.).

★ **Dr. James Marten** has been appointed chief chemist of Technicon Instruments Co. Ltd., the British subsidiary of Technicon Controls Inc., U.S.A.

★ The Shell Group has recently opened a new laboratory, the Tunstall laboratory, near Sittingbourne, Kent. The director is **Dr. C. G. Hunter**, formerly professor of physiological hygiene and associate professor of medical research in the University of Toronto. The laboratory will be concerned with the possible effects on man and other vertebrates of contact with products being developed by the Royal Dutch/Shell Group of companies.



Mr. John A. Croft



Dr. Pierre L. Balligand

★ **Mr. Joseph W. Smith** has been appointed director of contract operations of the Kellogg International Corporation, London, in place of **Mr. B. W. Jesser**, who has become assistant vice-president and director of engineering of the M. W. Kellogg Co. in New York. Mr. Smith has been director of construction.

★ **Mr. John A. Croft**, deputy chairman and managing director of Crofts Engineers (Holdings) Ltd., has been appointed chairman of the company and its principal operating subsidiary companies.

★ **Dr. Pierre Louis Balligand** is to succeed **Dr. Hubert de Laboulaye** as Deputy Director General in charge of the department of technical operations of the International Atomic Energy Agency. Dr. Balligand is the head of the large research reactors division of the French Commissariat à l'Energie Atomique. He has also organised a test reactor research group with the aim of normalising in-pile experiments and arranging dosimetry and flux measurements studies. Dr. de Laboulaye is returning to a senior position with the French Commissariat à l'Energie Atomique.

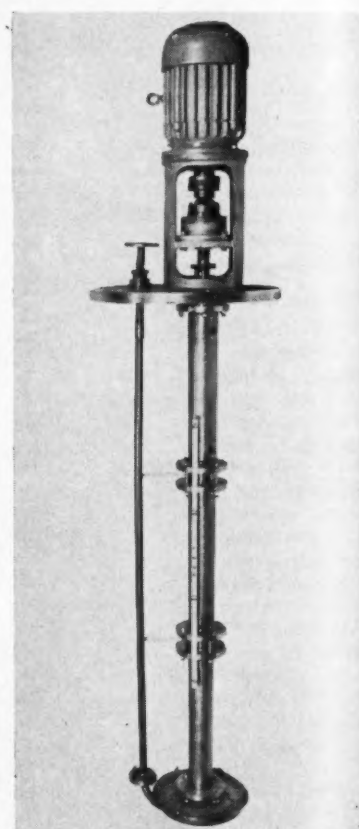
★ **Mr. K. Clarke** has been appointed assistant export manager of Acheson Colloids Ltd. He joined the Acheson organisation seven years ago. After several years as a senior engineer concerned with both U.K. and export sales development, he was transferred to Acheson Dispersed Pigments Co. as sales supervisor three years ago.

★ **Mr. E. F. Coppock** has been appointed group financial controller to Metal Industries Ltd. He succeeds **Mr. P. Jardine**, who is taking up full-time directorships with J. G. Statter & Co. Ltd. and Minerva Mouldings Ltd., two Metal Industries subsidiaries.

★ **Mr. Philip V. Colebrook**, managing director of Pfizer Ltd., has been appointed chairman of the board of directors of all companies within the Pfizer Group. He replaces **Mr. Richard C. Fenton**, who has been appointed an operations vice-president of Pfizer International, with headquarters in New York, and responsibility for the company's operations in Europe, the Middle East, Africa and Canada.

★ The death was announced recently of **Sir Oliver Lyle**, vice-chairman of Tate & Lyle. Although his whole life was devoted to sugar refining, he was particularly interested in fuel technology and was the acknowledged expert on the economic use of steam. His book, 'The Efficient Use of Steam', first published in 1947, is a classic on this subject. Oliver Lyle was that rare phenomenon, a first-class engineer with a broad humanistic outlook; this combination was responsible for the great esteem in which he was held by all at the Lyle sugar refinery which, under his management, was converted into one of the world's most efficient industrial plants.

★ **Mr. C. Vickers** has been appointed general sales manager of Ferro Enamels Ltd. In his capacities of director of the Vitreous Enamel Development Council and vice-chairman of the Hardware Manufacturers Association, he has been prominently concerned in the publicising of enamelled products.



The above photograph of the Appleton & Howard Gush Type 'S' centrifugal chemical pump which appeared on page 87 of the February issue was inadvertently reversed

# What's New



## in Plant • Equipment • Materials • Processes

CPE reference numbers are appended to all items appearing in these pages to make it easy for readers to obtain quickly, and free of charge, full details of any equipment, machinery, materials, processes, etc., in which they are interested. Simply fill in the top postcard attached, giving the appropriate reference number(s), and post it.

### Steam trap

A steam trap, offered by Midland Industries Ltd., has been designed to discharge condensate at steam temperatures consistently from no load to maximum.

There are six components with only one moving part, the valve. All internal trim is renewable *in situ*.

The valve is held on its seat by the conversion of the kinetic energy of flashing condensate into pressure energy. When this pressure is destroyed by recondensation the valve opens to discharge the condensate from the equipment being drained.

It is said to be suitable for use on applications from 5 to 250 p.s.i. with a manganese bronze body or 5 to 400 p.s.i. with a stainless-steel body.

CPE 1640



New steam trap made by Midland Industries Ltd.

### Filter for insulating oil

A portable insulating oil filter which has its own separate pumping set is offered by Stream-Line Filters Ltd. It is easily transported and can be operated by one man. Being unheated, it can be operated where an electrical supply for heaters is not available.

Provided any free water is decanted before filtration, the filter is said to

be able to deal with the remaining traces of moisture up to a maximum quantity of about  $\frac{3}{4}$  pint. Accumulation of solid impurities can be removed in the general way by reversal with compressed air.

The use of this filter is said to solve the problem of taking large plants to inaccessible places and enable insulating oil in switchgears, tap changers and other equipment to be upgraded in a single passage. The only electrical current necessary is that required for the electrical motor—about 200 W.

CPE 1641

### Isotope monitor

Equipment which measures and records the activity of solid radioisotopes dissolved in water is offered by Elliott Nucleonics Ltd.

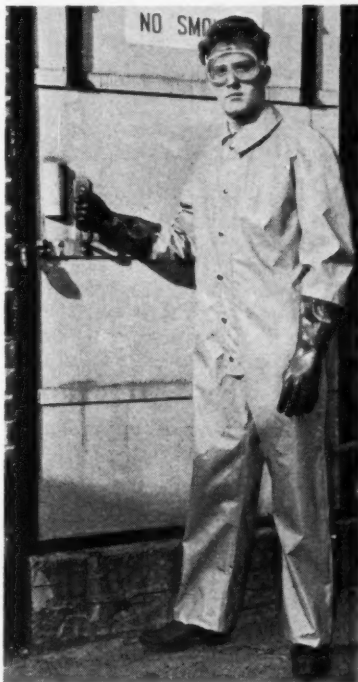
The sensitivity is said to be such that a specific activity for drinking water well below the maximum permissible level for mixed fission products can be detected.

The monitor consists of a sampling unit and an indicating unit. The sampling unit contains a Geiger-Muller tube surrounded by a bed of ion-exchange resin. Water is passed through the resin bed at a controlled rate, and dissolved solids, including any fission products present, are retained in the resin.

The beta-gamma activity emitted by the solid radioisotopes are detected by the Geiger tube. The output from the counter tube is fed to an indicator unit which records continuously the mean counting rate and, if required, actuates an alarm on reaching a predetermined level. The measuring circuits employ transistors for a high degree of reliability.

The sampling is normally carried out over a weekly period in which 20 l. of water are passed through the ion-exchange resin at a controlled rate, after which the resin is replaced.

CPE 1642



### Protection from splashes

The photograph shows a proofed boiler suit to be worn where danger of wide-scale splashing occurs. It is made by Northide Ltd. of high-twist, low-tenacity nylon, proofed and impregnated with PVC. There are special fastenings to eliminate penetration at buttonholes, etc. Its colour is light green, which makes the wearer conspicuous on a crowded factory floor and easy to locate in an emergency.

CPE 1643

### Safety for burners

A flame failure control designed to provide a safety system for oil, gas or pulverised fuel burners is offered by



Photoelectronics (M.O.M.) Ltd. It operates on the modulation of the flame irrespective of colour or background radiation. The unit will immediately cut off the supply of fuel should the flame go out.

In addition to operating as an on/off device in conjunction with a solenoid valve, the equipment can also be fitted with an automatic sequence unit to provide a fully automatic control system for the burners.

The equipment has indicating lights to show the condition of operation and the photocell is contained in a cast aluminium tube for easy mounting.

**CPE 1644**

### Feeder

The *Vibra* screw feeder made by Simon Handling Engineers Ltd. incorporates a screw mounted on a vibrator in such a way that the screw, screw trough, screw bearings and discharge tube vibrate as one assembly while the screw rotates.

Feed rates are proportional to the speed of rotation of the screw and are infinitely variable over a range of about 50 : 1.

The vibratory action of the feeder is said to overcome sticking, bridging and flooding and a constant level of material is maintained over the screw to eliminate feed rate fluctuations.

**CPE 1645**



Explosion-proof motor base for use where inflammable liquids, vapours or atmospheres are liable to be encountered

A computing system, RADIC, made by Redifon Ltd., has started work on calculations for the design of super-fractionating distillation columns for the refineries of a major British oil company. The calculations are mainly concerned with heat transfer and mass and heat balance problems.

There are about 100 trays in each distillation column, and for each tray it is necessary to solve a second-order differential equation in six variables. The volume of calculation is too great to be handled by normal methods, and even a conventional analogue computer would require a large and expensive assemblage of operational amplifiers to do the job.

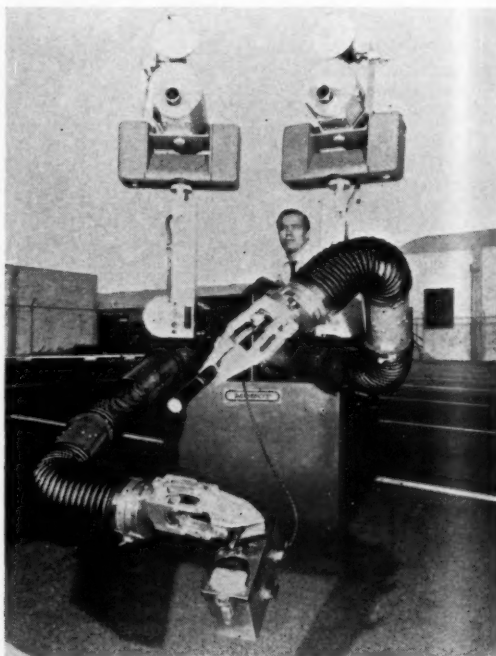
The advantage of using the RADIC

### Design by computer

(Redifon analogue-digital computing system) for this work lies in the fact that the system incorporates a digital storage unit which can be used for holding partial results of calculations. If this unit is arranged to store the initial and end values for each tray in the distillation column, the whole set of calculations can be performed with a relatively small number of operational amplifiers. Using such a method the calculations take about 1 sec. per tray to perform, or about 2 min. for the whole distillation column.

The system is basically an analogue computer with the extra facilities of digital input, output, storage and control.

**CPE 1647**



Holding a Geiger counter in its 'hands', the remote control robot demonstrates how it could substitute for man in dangerously radiated areas

### Inflammable liquid handling

The main cause of fire and minor explosions when inflammable liquids are mixed is when vapour in the immediate atmosphere becomes ignited from the arcs of the electric motor brushes.

This hazard, it is claimed, can be eliminated with a high-speed blender motor base which mixes at speeds of 8,000 to 16,000 r.p.m. It is marketed in the U.K., prior to later manufacture in Britain, by the Waring division of Winston Electronics Ltd.

It is designed for use with Pyrex glass containers of about 1 qt. capacity.

**CPE 1646**

### Mobile robot

A mobile robot that can twist its 6-ft. steel arms is offered by Hughes Aircraft Co. The remote control handling machine, *Mobor*, was designed for use in dangerous areas.

It has soft inflated pads on its hands in which the pressure can be delicately controlled by the operator.

Two television cameras, mounted on proboscis-like tentacles, focus on the hands and transmit the picture to the operator at a control console at distances of up to 100 ft. away. Microphones at the wrists permit the operator to hear the tasks performed by the hands.

**CPE 1648**

### Aeration blending

It is very difficult to achieve a perfectly homogeneous mixture of pulverised materials by ordinary mechanical blending methods. The Fuller *Airmerge* system has been designed to blend dry, pulverised, raw materials on a commercial scale. It is basically an aeration system—any dry powders that can be fluidised by aeration can also be blended.

This blending operation is carried out in a round silo with a substantially flat bottom—the level to which the silo is filled with material to be blended is about equal to the silo diameter. The silo bottom is covered with Fuller aeration units closely spaced to give a uniform distribution of air into the material over the entire dispersion face.

To effect blending, compressed air is led into one quarter section of the silo bottom in a volume sufficient to fluidise the material above that individual section. As a result of being expanded and at the same time becoming fluid this material rises above the level of adjacent quadrants and flows across them at a rapid rate. At the bottoms of the temporarily inactive quadrants a small amount of compressed air is meanwhile released.

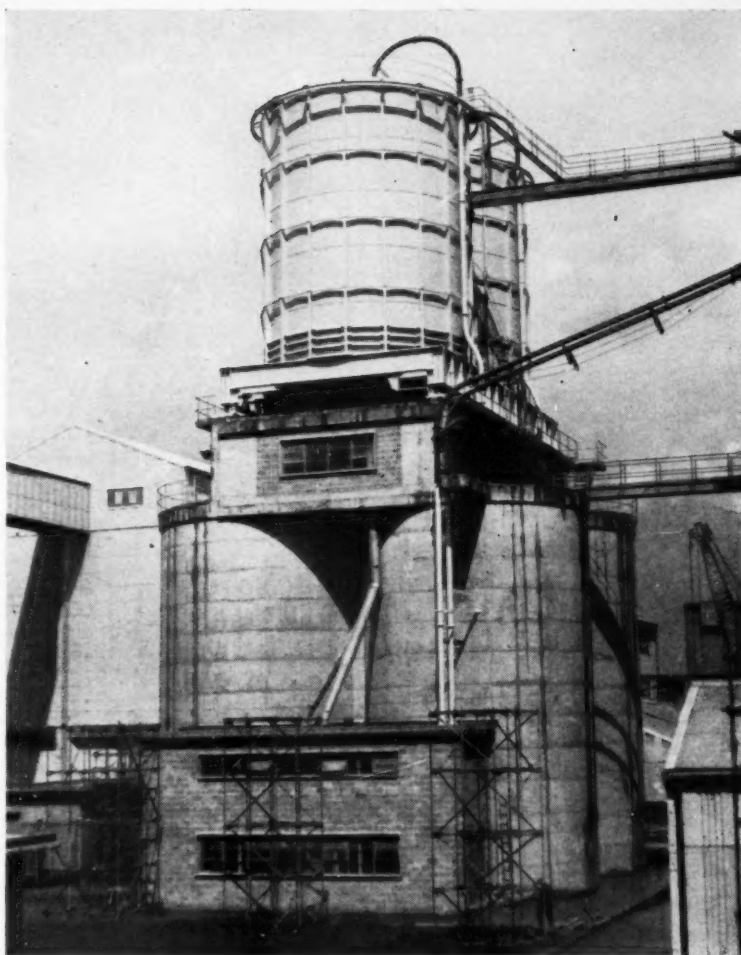
The rising column of expanded material in the actively aerated quadrant is partly surrounded with heavier material which tends to slump over into the active quadrant where it subsequently becomes aerated, expands, rises and flows outward.

Thus a strong and continuous roll-over motion in a vertical circuit is obtained which results in a most intensive and thorough mixing of silo contents from top to bottom. The intensive aeration is periodically switched to a previously inactive adjacent quadrant—and then successively to each of the quadrants in rotation. After one circuit of the silo bottom has been completed all the material in the silo has been put in motion.

Results secured by simple quadrant blending may be further enhanced by applying the air to the active quadrant in pulsations rather than under continuous flow. With any material pulsed application of the aeration air achieves a higher degree of fluidity and corresponding greater mobility.

The system is said to be suitable for use in either batch or continuous operations. For serving a continuous process two or more such silos are required so that one can be feeding the process while a batch is being accumulated and blended in the other.

**CPE 1649**



Raw meal blending and storage silos of the aeration blending system

### Activated charcoal filters

Alfred Bullows & Sons Ltd. offer a range of activated charcoal filters. These have been designed for use in compressed-air systems where oil in the air stream is not acceptable. They claim to remove all traces of oil from the air and also eliminate the smell generally associated with oil in aerosol form.

Each filter consists of an outer case and lid with a cartridge of activated charcoal and conforms to British Standards where applicable. Provision is made on all filters for four-point wall mounting.

The cartridge of activated charcoal removes oil from the air stream by adsorption and is therefore an expendable item which requires changing at intervals, dependent upon operating conditions. An average life of a cartridge element is 1,000 to 1,500 working hours.

Air inlets are in the bottom and air outlets at the side of the filters, so that when changing the cartridge it is not necessary to break the air connections. The lid, which is sealed with an 'O' ring, is removed, cartridge changed and lid replaced. **CPE 1650**

### Dryer

Aeromatic Ltd. offer a continuous-process dryer which works on the fluidised-bed principle.

The dryer can be adapted for varying speeds and capacities. The machinery is said to be suitable for all types of chemical, pharmaceutical, plastic and other granular materials.

The principle of the dryer is that hot air is blown through a conveyor belt of stainless-steel wire netting on which the material progresses while it is dried. **CPE 1651**



# Nuclear Notes

## Superheat reactor

A development reactor to increase the efficiency of nuclear power by developing nuclear superheating is to be built by U.S. General Electric in conjunction with seven New York State utilities and will cost \$8 million.

The new plant will be used to develop superheat reactor fuel, to examine the performance of the reactor under various operation conditions and to test various superheat methods, including integral and separate superheat.

The reactor, rated at 15,000 thermal kW, will be built alongside the Vallecitos boiling-water reactor where earliest test programmes demonstrated the feasibility of nuclear superheat. It will be ready for operation next year.

## Remote control at Winfrith

An automatic remotely-controlled monorail installation has been designed by British MonoRail Ltd. to handle fissile materials at the Atomic Energy Establishment at Winfrith Heath.

The scheme permits remote selection of material from any of the seven assembly bays in the fissile material stores and its delivery to any one of twelve experimental stations in the reactor physics hall. Loads are picked up and transported by electric hoists suspended from powered carriages which run on a system of overhead monorails.

## Examination of pressure vessels

The U.K. Atomic Energy Authority recently took delivery from Mullard Equipment Ltd. of a mobile 4.3-million-V linear accelerator designed to make X-ray examinations of the pressure vessels of nuclear power stations during construction.

The machine will enable the welds in the thick steel walls of the pressure vessel containing the reactor cores to be radiographed on site during the building of a nuclear power station, with the minimum of disturbance to the constructional work.

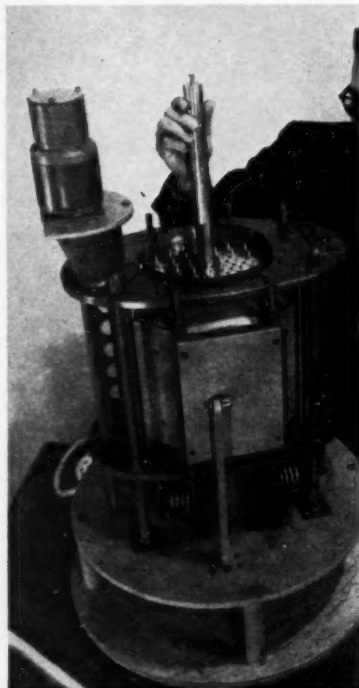
It will be used for the first time at the station being built for the Central Electricity Generating Board at Trawsfynydd.

The accelerator has been engineered into a self-contained unit. It can be rotated about both horizontal and

vertical axes for rapid, accurate alignment on to the specimen, and may be mounted on a tower, or suspended from suitable lifting tackle.

The entire vacuum and cooling systems have been incorporated in the accelerator unit, thus eliminating the problems of lengthy hose connections.

The control cabin housing the ancillary electrical and control equipment is a transportable weatherproof structure of fibreglass which may be sited up to 250 ft. away from the accelerator.



SPACE REACTOR

*This prototype atomic reactor was exhibited in Washington to the Joint Congressional Committee on Atomic Energy by Atomic International, a division of North American Aviation Inc. A full-scale prototype actually used for engineering tests, the reactor was built by the company as part of the A.E.C.'s SNAP programme (Systems for Nuclear Auxiliary Power). A mock fuel element is being inserted into the core of the reactor.*

## Exhibition in Cologne

Euratom will be taking part at Interschutz, the International Exhibition of Fire Fighting Equipment, Safety Appliances and Radiation Protection in Cologne from June 23 to July 2, 1961. It will provide a survey of European co-operation in radiation protection and of the level of developments reached in the various countries.

From Germany, the Federal Ministry for Nuclear Energy and Water Control in Bonn will give a display dealing with the problems of radiation protection and reactor safety, while the French Commissariat for Atomic Energy in Paris will illustrate protection against radiation during the transportation of radio-nuclides.

Apart from countries in the E.E.C. area, the United States will also make a contribution in the field of radiation protection. The State Department in Washington and the U.S. Atomic Energy Commission have started to prepare a joint display for Cologne. The British Association for Manufacturers of Industrial Safety Appliances will be taking part and showing a wide range of products which covers, in addition to conventional protective clothing, special clothing offering protection against radiation as well as radiation measuring instruments.

## Neutron telescope

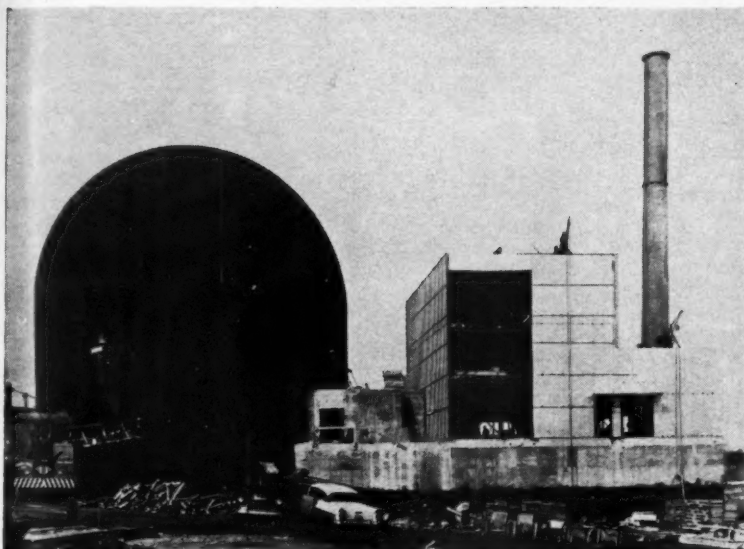
A sensitive electronic device which permits nuclear engineers to 'look' through the thick steel walls of an atomic reactor to see how much steam it is producing was described by Mr. S. Untermyer of U.S. General Electric before the American Nuclear Society at its winter meeting.

The 'neutron telescope' is basically a fast neutron counter in a special tube which can measure small differences in the steam output of selected fuel channels in the reactor.

The device, which is mounted above the core of the reactor, can be aimed accurately at a fuel channel from a distance of 20 ft. or more, and will count fast neutrons coming up out of that section of the reactor through 6 ft. of water and several inches of steel.

From the number of fast neutrons coming out of the reactor, the engineers can tell how much steam





#### POWER PLANT IN OHIO

*The first U.S. atomic power plant to be operated by a municipal utility will be the 11,400-kW station being built at Piqua, Ohio, by Atomics International, a division of North American Aviation Inc. It is part of the U.S. Atomic Energy Commission's power demonstration programme and will be completed this summer. An organic moderated and cooled reactor being installed in the dome-shaped housing will be the heat source. The building on the right will contain process equipment, a control room and offices.*

that part of the reactor is making, or literally how hard that area of the reactor is running.

Since water acts as a block to the passage of fast neutrons, if the reactor is not producing a lot of steam bubbles the number of neutrons counted by the 'neutron telescope' will be small. If the reactor is producing a lot of steam, fast neutrons can pass through easily and be counted by the device.

#### Euratom contracts

In carrying out its research programme, which covers the various peaceful uses of nuclear energy, Euratom uses the facilities of the branch establishments of its Joint Research Centre and those of the various organisations and firms in the member states.

The setting up of the Joint Research Centre is virtually completed. It consists of three branch establishments: the Ispra centre and the Central Nuclear Measurements Bureau, which are already in operation, and the Karlsruhe Trans-Uranium Institute, which is still under construction. Furthermore, the Commission is negotiating with the Netherlands concerning the setting up of a Joint Research Centre establishment at Petten.

Clearly the joint centre cannot carry out the entire Euratom research programme by itself and Euratom has therefore placed a number of contracts with various bodies and enterprises in the member countries.

Euratom has so far signed 70 contracts for varying amounts, representing altogether a commitment of \$27 million. The contracts were placed as follows: 20 in Belgium, 9 in West Germany, 19 in France, 4 in the Netherlands, 17 in Italy and 1 in Switzerland (which is not a member of the E.E.C.).

#### Uranium fuel for Formosa

Fabricated into 35 reactor fuel elements at General Electric's atomic power equipment department in San Jose, California, 23,818 g. of uranium fuel arrived recently in Formosa for the first nuclear reactor in that country.

General Electric also designed and built the open-pool research reactor which belongs to the National Tsing-Hua University. The reactor, rated at 1,000 thermal kW, will be one of the major facilities at the university's Institute of Nuclear Science.

The centre was partly financed by a \$350,000 grant from the U.S. Atomic Energy Commission under the 'Atoms for Peace' programme.

## CPE DIARY

**APRIL 19 TO 21** Annual conference of the **Institution of Plant Engineers** to be held at the Imperial Hotel, Blackpool. Details from the Institution of Plant Engineers, 2 Grosvenor Gardens, London, S.W.1.

**APRIL 20 TO MAY 4** **Engineering, Marine, Welding & Nuclear Energy** Exhibition at Olympia.

**APRIL 20 TO 22** Conference on **palaeomagnetism** to be held at King's College, University of Durham, Newcastle upon Tyne. Organised by the Institute of Physics and the Physical Society.

**APRIL 25** Annual general meeting and dinner and dance of the **Institution of Chemical Engineers** to be held at the Park Lane Hotel, Piccadilly, London, W.1. Details from the Institution, 16 Belgrave Square, London, S.W.1.

**MAY 4** Lecture on **some pathways in biosynthesis** to be given by Prof. Birch at 7.30 p.m. at the Chemical Society, Burlington House, London, W.1.

**MAY 8 TO 19** Course at **Harwell Reactor School for technical executives**. Details from the Manager, Reactor School, A.E.R.E., Harwell, Didcot, Berks.

**MAY 9 TO 17** International exhibition of **measurement, control, regulation and automation** (Mesucora) to be held in Paris. Details from Secretariat, 40 Rue du Colisee, Paris 8.

**MAY 10 TO 12** Second international conference on **materials handling** in Southport. Details from the Institute of Materials Handling, 32 Watling Street, London, E.C.4.

**MAY 27 TO JUNE 11** **Liege International Fair** to be held at Liege, Belgium. Details from Liege Fair, 178 Fleet Street, London, E.C.4.

**MAY 29 TO JUNE 3** Residential refresher course on **combustion engineering** to be held at Prestatyn Holiday Camp. Details from National Industrial Fuel Efficiency Service, Baltic House, Mount Stuart Square, Cardiff.

# New Books

**Kinetics Equilibria and Performance of High Temperature Systems.** Editors: G. S. Bahn and E. E. Zukoski. Butterworths, 1961. 80s. net.

This is a book in which the chemical and the engineering aspects of some chemical reactions are very closely connected so that the study can truly be described as chemical engineering.

The book is about many chemical reactions considered potentially useful as sources of energy for rocket propulsion. There are 33 papers contributed by members of companies and universities of the U.S. to a symposium held during November 1959 in Los Angeles.

Viewed as a whole, these papers are a stimulating example of a concerted attack on design problems, among which the thermodynamic aspects have been put first. Methods of estimating thermodynamic constants for reactions for which no specific data existed and of applying the partition functions in other cases are described. Because of the high temperatures, a wide use of 'ideal' laws is made with some justification, but it is not made clear what modifications have been found necessary when pressures of 1,000 atm. are also used.

The reader expecting to find reaction velocity constants given for these 'combustion' processes will be disappointed. Much of the work is based on instantaneous establishment of chemical equilibrium when a temperature and pressure are altered by physical constraints. Nevertheless, we read (paper 30, page 219), 'When chemical reaction is involved, significant departure from local equilibrium flow can result if thermodynamic and gas dynamic changes occur in terms of the order of, or smaller than, the local chemical relaxation times. This situation can prevail in most high-temperature flows of current interest'. Paper 30 goes on to discuss finite rates of reaction and their consequences in rocket systems.

The complex equilibria that may prevail give rise to the need for solving many simultaneous (some differential) equations, which when taken in conjunction with guesses about possible thermodynamic numbers, give rise to problems calling for high-speed computers. About half of the papers are concerned with the arranging of instructions for computers.

The final outcome of the thermochemical deliberations must, of course, be estimates of the thrust that can be expected from the rocket, and these hinge on the design of the nozzle, etc., and the efficiency of conversion of chemical energy into kinetic (flow) energy. Paper 30 touches on the nozzle question, but 'security' has presumably limited discussions of this kind.

The papers form a very useful source of references for there is a considerable bibliography. In style, each is commendably terse, which is one among many things for which we are indebted to the editors.

Congratulations go to publishers for the quality of the production and the speed with which the work has been completed. The latter is in keeping with the general impression of 'urgency' that prevails in the papers.

K. L. BUTCHER

**Process Characterisation.** By H. I. Waterman, with the collaboration of C. Boelhouwer and D. Th. A. Huibers. Elsevier Publishing Co., Amsterdam, London, New York, Princeton, 1960. Pp. 137. 38s. net.

In four chapters headed introduction, description of physical and chemical process courses, applications of the characterisation to chemical processes and correlation of physical equilibria, the authors set out to introduce and to show the usefulness of a relative simple mathematical expression and to correlate data of chemical processes (also of complicated pattern) and of physical equilibria. The mathematical relation introduced as a 'characterisation of the process' is a relation between two variables and generally takes the form of a hyperbolic function, with two constants (in a few cases three constants) which depend on the conditions.

For a chemical process the variables are based on three properly chosen 'components' which generally are the starting material, the product or products and the by-product or by-products. The variables are then fractional amounts of the product(s) and of the by-product(s). For the physical equilibria the variables are fractional concentrations of the components.

Many examples are given to demonstrate the usefulness of the introduced correlation. For the chemical processes they are chiefly chosen from research work done in the Delft laboratories and lie in the field of alkylation, biochemical processes, cracking, halogenation, hydrogenation of fatty acids and sugars and isomerisation. For the physical equilibria a few examples are given for vapour-liquid equilibria of binary mixtures and liquid-liquid equilibria of ternary systems.

The examples given show that the suggested correlations can be useful for complex processes, provided that essential components can be chosen. The advantage lies in the potential considerable reduction of the number of experiments necessary to obtain an overall picture of the process. The book also gives an excellent opportunity to get acquainted with some of the work done by Prof. Waterman and his pupils. In both these respects the book is interesting.

However, a disadvantage felt by this reviewer is that the content of the book is not quite balanced, because it contains too much material which has no direct bearing on the actual subject, nor is any relation indicated. This refers, for example, to the remarks made on reaction kinetics. It has correctly been pointed out by the authors that the correlations as given are empirical in nature and have no bearing at all on kinetics. Also the introductory remarks on the vapour-liquid equilibria seem superfluous. Moreover, these passages are common property for those working in the field.

On the other hand, it is felt that the presentation lacks a critical examination on the validity of the equations for general application, especially with respect to a criterion as to the choice of the three components. Based on the necessary additivity of a property of the three components to be chosen, such a criterion can be established. The book is useful for research workers. It would have been more convincing had the authors restricted themselves strictly to a discussion of the actual subject, particularly to that of the correlation of chemical process data. The presentation meets high standards.

The reviewer announces with deep sorrow that the principal author of the book, Prof. H. I. Waterman, died suddenly from heart failure less than two years after retirement from the chair of chemical technology at the Delft University and a few months after the publication of this book. He

will be missed by his colleagues and friends, especially because of his ceaseless efforts to promote chemical technology science, of which this, his last published work, is an example.

P. M. HEERTJES

**Thermochemistry for Steel-making. Volume I.** By John F. Elliott and Molly Gleiser. Pergamon Press, Oxford, 1960. Pp. viii + 296. 75s. net.

This is the first of a series of volumes which is intended 'to collate, consolidate and summarise in one place the available data pertinent to the physical chemistry of steel-making'. It is the result of a programme of work sponsored by the American Iron and Steel Institute in the Department of Metallurgy of the Massachusetts Institute of Technology.

The book is divided into four sections. The first of these, on the physical properties of the elements, is short and, apart from some standard handbook information, contains only one table, listing the densities, thermal conductivities, viscosities and surface tensions of some liquid metals. The data are limited and no references are given.

The second section is quite different and consists of a detailed compilation of the most recent information on the thermodynamic properties of 45 selected elements. The range selected is wide and, apart from those elements of direct interest in steel-making, includes most of the common metals, some rare gases and the halogens. In some cases, the number of physical states chosen seems excessive, e.g. for carbon, graphite and the ideal gases C, C<sub>2</sub> and C<sub>3</sub>. The data tabulated are the heat capacities, enthalpy increments, entropies, free energy functions and enthalpies and free energies of formation for states other than the reference state, from 298° to 3,000°K. The values are almost all taken from existing well-known compilations and very little new critical contribution has been made.

In the third section, standard enthalpies and free energies of formation of carbides, nitrides, oxides, phosphides, silicides and sulphides are tabulated. Here again the scope is wide and many valuable data, scattered throughout the literature, have been collected though, as before, full use has been made of previous compilations which are extensively referred to. To include data for K<sub>2</sub>O, K<sub>2</sub>O<sub>2</sub>, K<sub>2</sub>O<sub>3</sub>, KO<sub>2</sub> and KO<sub>3</sub> was surely an excess of zeal! As stated in the foreword, a revision of

the well-known U.S. Bureau of Mines Bulletin No. 584 was in progress while this book was being prepared and the reader is referred to this revision for enthalpy and entropy increments. Unfortunately some of the data tabulated in this book will be inconsistent with the latest bulletin and will therefore be out of date. This discrepancy will not be important in rough calculations, but for exact work a reassessment may be necessary.

The last section, on vapour pressures, is full of pitfalls for the unwary. In few fields of study can there be more conflicting data and unresolved discrepancies and the editors rightly point to the main difficulty, i.e. the lack of knowledge of the vapour species, arising from dissociation and disproportionation.

Taken as a whole, this book falls not far short of being a compilation from compilations and this is a serious defect. Every time a datum is uncritically reproduced it assumes an increased, and usually unwarranted, authority and the task of assessing it in its true perspective is less likely to be undertaken. This leads to difficulties in comparative calculation. There are many who feel that the rate at which widely used thermochemical data are accumulating today has created a need for an international authority whose task would be to publish 'best values'.

This volume in the series will be of interest to few who are not concerned with the thermochemistry of steel-making, and some of those who are may feel that it falls too much between two stools and will continue to use their own charts and reference material for rough calculations and to refer to the more authoritative compilations or the original literature for exact work. The list of contents of future volumes in the series stated in the foreword includes nearly all those topics of special interest to steel-makers and research workers in the field which are not collected together elsewhere. One looks forward, therefore, to these future volumes with anticipation.

J. W. TOMLINSON

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**Die Schwefelsäurefabrikation (The Manufacture of Sulphuric Acid).** By Bruno Waeser. Fiedr. Vierweg & Sohn, Braunschweig, 1961. Pp. 488. DM 76 net.

Lunge's classic on sulphuric acid manufacture has dominated the entire literary field on that subject for close on a century. It is therefore inconceivable that any new book on this subject, especially if it is German, will deviate from the Lunge tradition. This recently published treatise on sulphuric acid manufacture only claims to be a revised, up-to-date version of the 'Handbook of Sulphuric Acid Manufacture', which first appeared in 1930. Such a revised version has been long overdue.

Chapter 1 deals with some general and theoretical principles. Chapter 2 contains a résumé of the most important patents which have appeared in Germany, U.S., U.K., France and other Western countries. Chapter 3 discusses raw materials. Chapter 4 describes the technical production of SO<sub>2</sub>. Chapter 5 discusses roaster gas scrubbing and cooling and Chapter 6 deals with the recovery of 100% SO<sub>2</sub>. Chapter 7 describes nitrous oxides and Chapter 8 is on contact processes. Chapter 9 is devoted to the H<sub>2</sub>SO<sub>4</sub> wet catalysis process. Chapter 10 discusses methods of cleaning, concentration and utilisation of waste acids. Chapter 11 examines corrosion and Chapter 12 analytical tests and process control. The final Chapter, 13, is on economic problems associated with sulphuric acid manufacture.

An amazing fact revealed in Chapter 2 is that, from 1930 to 1959, 2,250 patents were filed in connection with sulphuric acid manufacture. It is, of course, impossible to ensure that every relevant patent on this subject has been included, yet in order to compile this list the editors must have had unlimited patience together with remarkable diligence. In view of the fact that the bulk of new discoveries in this field has been in the contact process, Chapter 8 is the most comprehensive section.

Dating from Roebuck's discovery of the lead chamber process in 1746, sulphuric acid manufacture is probably the oldest branch of the modern chemical industry; it is also the most vital part of this industry. The authors of this treatise must therefore be congratulated on having compiled another all-embracing treatise which does credit to the German tradition in this field.

I.L.H.

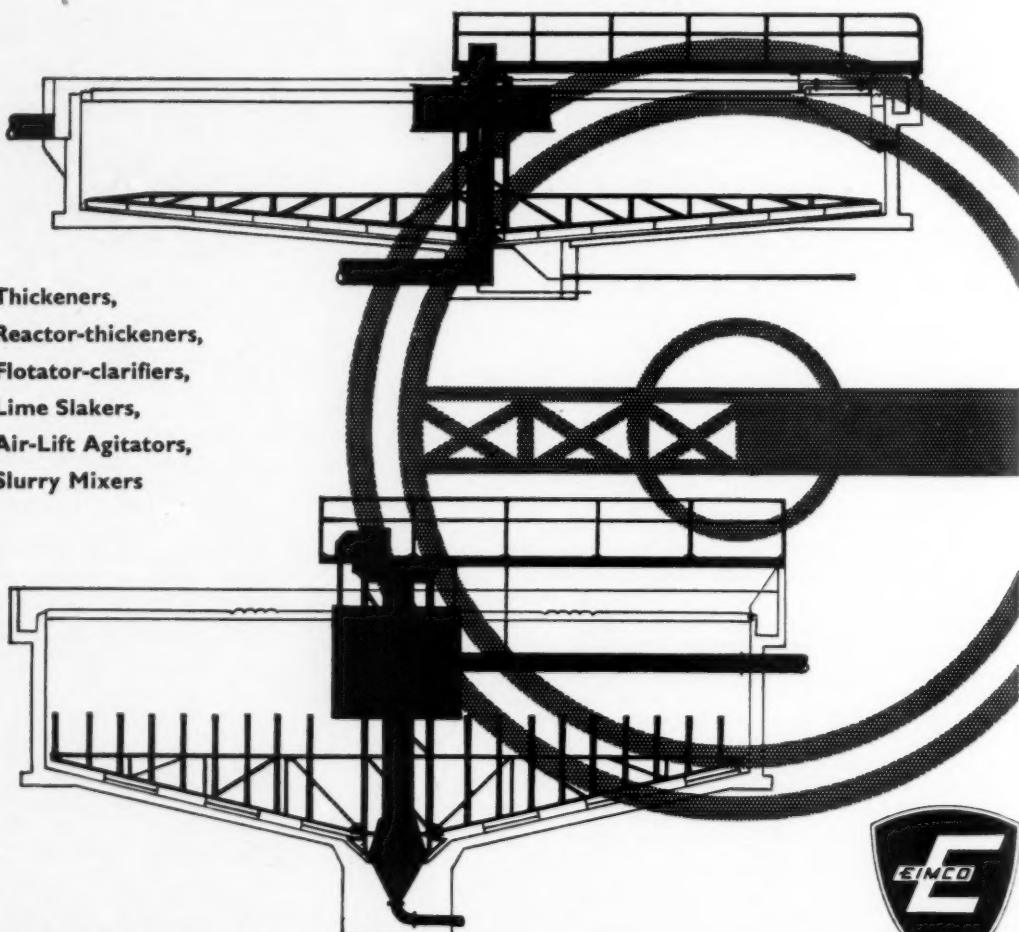


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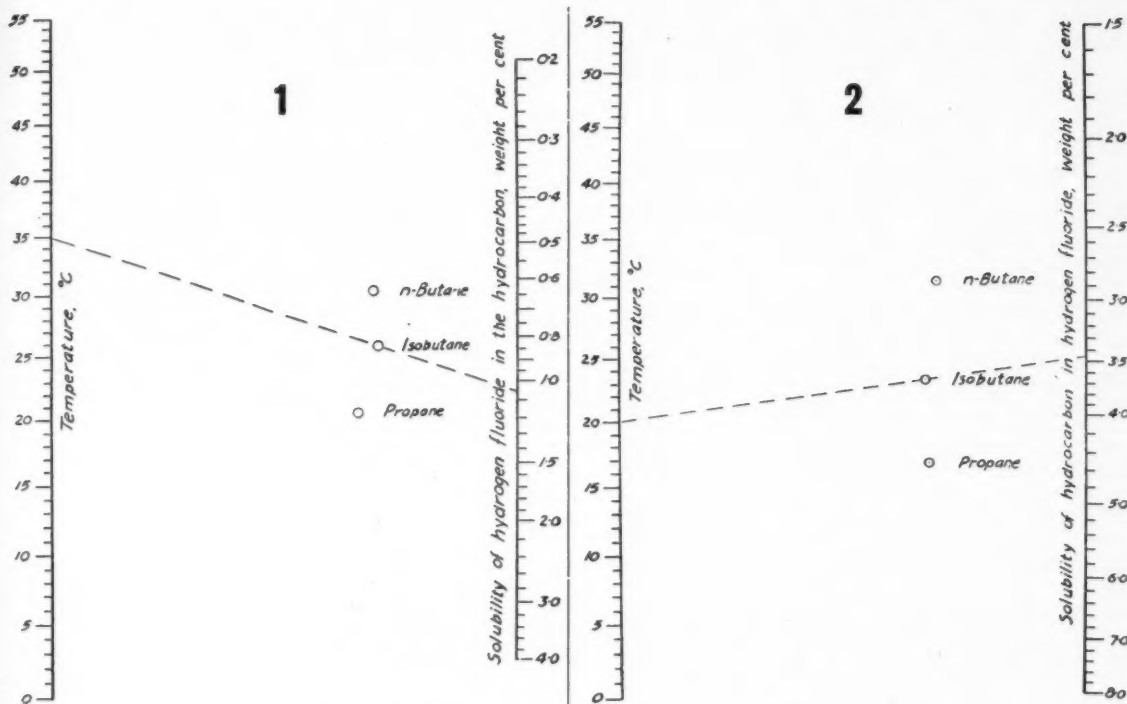
P.2699

# Solubilities of

## (1) Hydrogen Fluoride in Hydrocarbons

## (2) Hydrocarbons in Hydrogen Fluoride

By D. S. Davis\*



The economics of the hydrogen fluoride alkylation process for the production of aviation-grade gasoline depends upon the recovery of hydrogen fluoride from effluent hydrocarbon streams. For this reason estimation of the solubility of anhydrous hydrogen fluoride in isobutane, *n*-butane and propane at various temperatures is important. A reliable investigation<sup>1</sup> has resulted in the correlation

$$\log W_1 = -\frac{A_1}{T} + B_1 \quad (1)$$

where  $W_1$  = solubility anhydrous hydrogen fluoride, weight percentage in the hydrocarbon phase,  $T$  = temperature, °K., and the constants have the following values:

Solvent	$A_1$	$B_1$
Isobutane	1010.6	3.30518
<i>n</i> -Butane	1061.8	3.30173
Propane	1225.3	4.24192

Conversely, an investigation<sup>1</sup> of the solubilities of pure liquid isobutane, *n*-butane and propane in anhydrous hydrogen fluoride has resulted in the equation:

$$\log W_2 = \frac{A_2}{T} + B_2 \quad (2)$$

where  $W_2$  = solubility of the hydrocarbon, weight percentage in the hydrogen fluoride phase,  $T$  = temperature, °K., and the constants have the following values:

Hydrocarbon	$A_2$	$B_2$
Isobutane	630.3	2.69027
<i>n</i> -Butane	569.0	2.32359
Propane	605.2	2.74152

The line co-ordinate chart (1), based on equation (1) and on these constants and constructed by means

of well-known methods,<sup>2</sup> extends the utility of the original data. The broken line on the chart shows that the solubility of hydrogen fluoride in isobutane is 1.05 weight% at 35°C.

The line co-ordinate chart (2) based on equation (2) and on these constants and similarly constructed demonstrates the converse of (1). As an illustration of the use of the chart, the broken line shows that the solubility of isobutane in hydrogen fluoride is 3.45 weight% at 20°C.

### REFERENCES

- E. B. Butler, C. V. Miles and C. S. Kuhn, *Ind. Eng. Chem.*, 1946, **38**, 1947.
- D. S. Davis, 'Nomography and Empirical Equations', Chapter 10. Reinhold Publishing Corp., New York, 1955.

\*Head, Department of Pulp and Paper Technology, University of Alabama.



## AUSTRIA

**Sulphuric acid plant**

Donau-Chemie A.G. is erecting a sulphuric acid plant in Mossbierbaum, near Vienna, under licence from Monsanto, U.S.A. The plant is scheduled to be completed at the end of the year. Donau-Chemie's sulphuric acid plant in Liessing, near Vienna, will be closed as soon as the new plant is on stream.

## LIBYA

**Water treatment**

A contract, awarded to William Bobby & Co. Ltd. for a water and power supply plant at Zliten, has been extended.

The Libyan Public Development and Stabilisation Agency, as part of its plans to improve water supplies in desert areas, accepted a tender of about £45,000 for the second phase of the work.

An electrodialytic desalting plant which purifies brackish desert well water was installed in Tobruk two years ago by William Bobby and is now in full production.

## AUSTRALIA

**Titanium oxide plant**

Laport Industries are to establish a £3.5-million titanium oxide plant in Western Australia.

The plant will be at Bunbury, 115 miles south of Perth. It will have a production capacity of 10,000 tons p.a. and is expected to start production by 1964.

The company already has a subsidiary company in Australia, Laporte Chemicals (Australia) Pty. Ltd., manufacturing hydrogen peroxide and peroxide compounds at Botany, New South Wales.

## MEXICO

**Thermal insulation**

The Cape Asbestos Co. Ltd. have taken a financial interest in Aislanes Industriales S.A. de C.V., of Mexico City, manufacturers of foamed polystyrene insulation products and asbestos pipe covering for low-temperature work. The company will soon begin manufacture of *Caposite*, amosite pipe sections for high-temperature insulation. A new factory is under construction by Aislanes Industriales S.A. de C.V. in Santa Clara, about 15 miles north of Mexico City.

## ITALY

**Basic chemicals manufacture**

Mobil Chimica Italiana SpA., a newly formed Italian chemical company affiliated with Socony Mobil Oil Co. Inc., is to build a major plant at Naples to manufacture benzene, ethylbenzene, orthoxylene and paraxylene.

The estimated total initial output is 130,000 metric tons p.a., of which more than 75% will be represented by benzene and orthoxylene production. Raw materials will be supplied from an adjacent refinery operated by Mobil Oil Italiana.

## BRAZIL

**Polyethylene expansion**

The capacity of the Union Carbide's polyethylene plant near Santos is to be expanded from 9 million to 24 million lb. p.a. Design and engineering work for the plant extension have been completed and construction has started. Completion is planned for late this year.

This expansion is designed to satisfy the growing requirements of the Brazilian market for some time to come.

## UNITED ARAB REPUBLIC

**Water treatment**

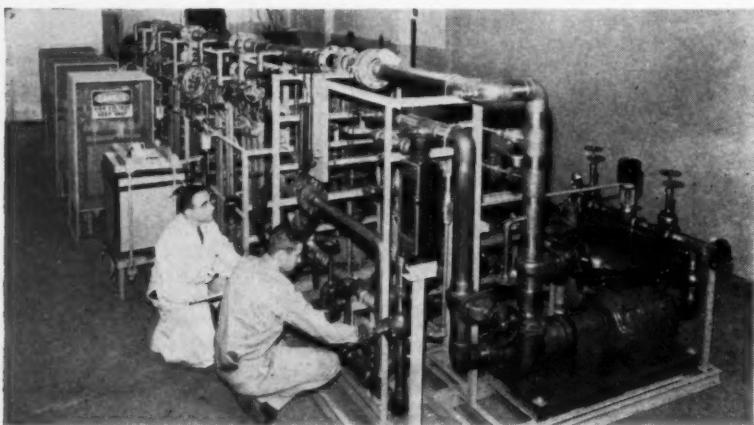
The Czechoslovak foreign trade corporation of Strojexport is to supply the United Arab Republic with a water treatment plant having a capacity of 100,000 cu.m./24 hr. This plant, intended for Cairo, is the second of its type that the corporation will have built in Cairo. The plant will have a capacity of 300,000 cu.m./24 hr., which is the largest project of its kind in the Middle East.

## NETHERLANDS

**Ammonium nitrate treatment**

The Société Belge de l'Azote et des Produits Chimiques du Marly (S.B.A.) of Liège, Belgium, have received a contract from Mekog for the engineering of a unit for the neutralisation and concentration of ammonium nitrate solutions under atmospheric pressure.

This unit will be built at Pernis and have a capacity of 285 tons/day of 100% ammonium nitrate.



## UNITED STATES

Largest of 12 electrically powered water-desalting plants which will soon provide pure water from highly mineralised wells at U.S. Air Force missile bases is shown here being prepared for shipment from Ionics Inc. plant in Cambridge, Mass., U.S.A.

The new plant will produce 86,000 gal./day of pure water for all domestic personnel uses as well as process and cooling water at a missile site near Ellsworth Air Force Base, South Dakota. It operates on the 'electrodialysis' principle, which utilises small quantities of electrical energy to remove dissolved salts and minerals from brackish water supplies.





Polyester film plant at Dumfries

## CPE Company News

### Opening of Scottish plant

The new I.C.I. plant for manufacturing *Melinex* polyester film was officially opened at Dumfries, Scotland, last month.

The plant, which has an annual production capacity of 2,000 tons, is housed in a factory which, until three years ago, was used for the manufacture of *Ardil* protein fibre.

### Flow meter manufacture

Controls Co. of America has formed a British subsidiary. The new company, Controls Co. of America (U.K.) Ltd., will be under the direction of the American organisation's Canadian subsidiary.

Assembly operations have begun at a factory at Woking which will become the headquarters of a planned expansion leading eventually to a chain of factories throughout Britain. The initial assembly programme includes flow controls for oil-fired boilers, warm-air heating equipment and automatic washers.

### Acrylic fibre expansion

Chemstrand Ltd.'s £3½-million *Acrilan* acrylic fibre plant at Coleraine, Co. Londonderry, is to increase production capacity by 50% from 10 to 15 million lb. of *Acrilan* p.a.

This is the first phase of a two-phase expansion plant which will be completed by mid-autumn of this year. Engineering design work has also been started to increase capacity to 25 million lb. of *Acrilan* p.a. by the end of next year.

Chemstrand Ltd., who started at Coleraine in 1958 on a 70-acre site,

now cover 90 acres and are purchasing a further 98 acres of land adjoining the present factory site.

### Liquid oxygen distribution

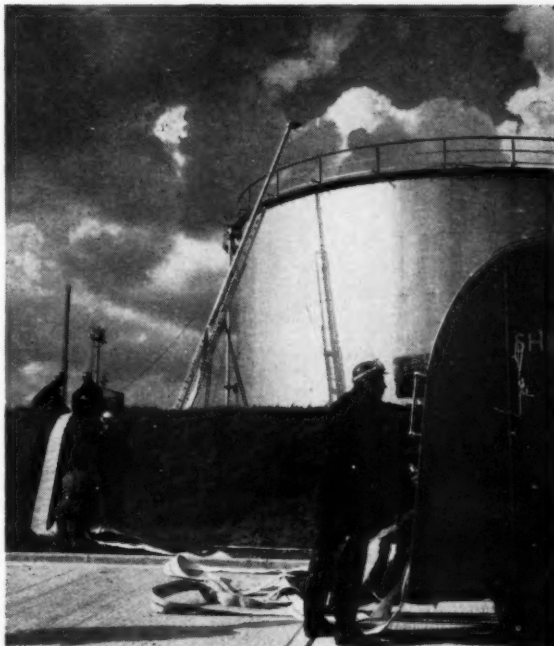
An extensive programme for modernising, improving and extending liquid oxygen distributing and dispensing equipment has been launched by British Oxygen. Under the new system liquid tankers, fitted with electrically operated pumps, deliver liquid into an evaporator in consumers' works at a pressure up to 300 p.s.i.

New vacuum insulated evaporators have been designed and manufactured by the company's engineering division, and existing cold evaporators are being modified to take pressure filling. The system will be extended to include liquid nitrogen and liquid argon.

With these new units and the modified cold evaporator, fresh supplies of liquid can be pumped in without interruption of customer's demand. The pump filling operation is twice as fast as the conventional decanting method.

### SAFETY IN WORKS

A portable foam mast rigged on a storage tank during a training exercise for the works' fire brigade at Shell Chemical Co. Ltd.'s Carrington works



# Orders and Contracts

## Sea-water evaporators

Richardsons, Westgarth & Co. Ltd. have received an order from the Air Ministry for four 12,000-gal./day sea-water evaporators, together with associated equipment.

These evaporators will provide drinking water for R.A.F. personnel at Sharjah in the Trucial Oman, and Masirah Island off the coast of Muscat and Oman.

## Sulphur extraction plant

R. & J. Dempster Ltd. have been licensed recently to market the *Stretford* sulphur extraction process, and have received an order for a plant to deal with about 11 million cu.ft./day of refinery gas. The plant will be delivered and erected at Antwerp, and is the first operating on this process to be ordered.

## Weedkiller plant

Fisons Ltd. and Constructors John Brown Ltd. have been awarded a £2-million contract by Techmashimport, for the erection in the U.S.S.R. of a 4,200-ton-p.a. MCPA (hormone weedkiller) plant and a 12,000-ton-p.a. dimethylol ethylene urea plant.

Both plants are expected to be on stream by next year.

## Computer for chemical plant

A computer system for the automatic control of a chemical plant has been ordered from Ferranti Ltd. by I.C.I. Ltd. This order marks a turning point in the utilisation of the electronic computer in Britain, extending its role

from that of a passive instrument to an active means of control.

The computer becomes an integral part of the industrial plant. Results of calculations take the form of electrical signals which directly control operations in the plant.

I.C.I. have ordered the system for one of their chemical plants at Fleetwood, Lancs., where it will take over the functions of about 100 conventional control devices. The equipment is expected to be in operation by June 1961.

## Proportioning equipment

Simon Handling Engineers Ltd. have been awarded a contract by Strojimport for the supply of automatic proportioning equipment for ingredients used in the manufacture of rubber for footwear by Svit np. of Gottvaldov, Czechoslovakia.

The value of the contract is more than £60,000 and the completed order is to be shipped early in November 1961.

Svit np. is one of the largest shoe factories in the world and turns out some 183,000 pairs a day. This equipment will introduce closer process control and reduce manpower requirements by the elimination of manual weighing and feeding of ingredients to the mixing machinery.

## Correspondence

### Industrial revolution

SIR,

I was delighted to see your historical editorial 'From crucible to reactor' in the February issue. I do not think that anybody knows why the Industrial Revolution occurred in Britain when it did, though we seem to be feeling our way towards a few more likely explanations than those biographical ones which have served textbook writers for so long.

Once textile output was increased, there was clearly a need for new ways of bleaching and improvements in soap manufacture. This took a further leap forwards after the Napoleonic Wars when Leblanc soda came to be made here on a large scale. And the two branches joined when the Leblanc manufacturers started to make bleaching powder as a by-product.

But, in Lancashire at any rate, the two branches were geographically distinct until the middle of the 19th century, Leblanc and soap being usually on the Merseyside and the big bleaching powder people being in south-east Lancashire.

K. BARKER

London School of Economics and

Political Science,  
Houghton Street,  
London, W.C.2.

## Computers in process control

What is the role of the computer in a process? What is its justification? How may it be readily integrated with the rest of the process instrumentation? In an article by M. James in the April issue of *Automation Progress* a rather special view of the subject is taken concentrating on the design features of a unique time-shared analogue computer for on-line process control and examining some of the ways in which it may be applied. Other articles in the same issue are *Hydraulic Servomechanisms—3*, by N. A. Shute and D. E. Turnbull, and *X-Ray Methods of Automatic Analysis*, by D. C. Munro.

The following articles appearing in our associate journals may be of interest to readers of CPE.

**Food Manufacture**—Review of the Dairy Industry, by W. G. Wearmouth. Review of Canning and Freezing, by D. D. Dickinson. Review of Jams and Preserves, by J. M. Colquhoun.

**Fibres and Plastics**—Special feature on polyester and epoxy resins. Low-temperature Radiant Heat Drying, by H. L. Smith. Analysis and Testing of Plastics, by G. C. Ives.

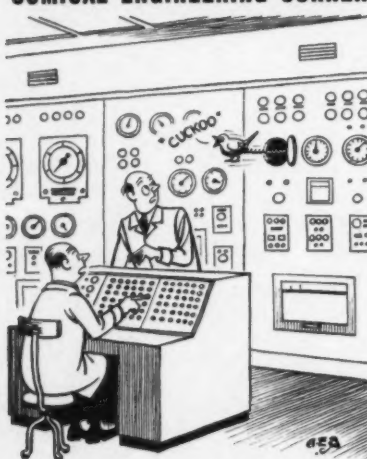
**Petroleum**—Storage Tank Life—Extension through Design and Treatment, by C. K. Aldrich. Fire Precautions at a Middle East Oil Terminal, by S. Harrison. The Petroleum Industry Fights Corrosion.

**Paint Manufacture**—Some Factors Effecting Gloss of Emulsion Paints, by J. Wood and P. J. Fry.

**Manufacturing Chemist**—Small-scale Manufacturing Equipment—Sifting and Grinding, by C. W. Ridout. Carbohydrates in the Chemical Industry—Fermentation Processes, by G. Machell.

Specimen copies of these journals and subscription forms are available from the Circulation Manager, Leonard Hill House, Eden Street, London, N.W.1.

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